ELECTRIC MINE SIGNALLING INSTALLATIONS

G. W. LUMMIS PATERSON

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ELECTRIC MINE SIGNALLING INSTALLATIONS

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A PRACTICAL TREATISE ON THE FITTING-UP AND MAINTENANCE OF ELECTRICAL SIGNALLING APPARATUS IN MINES

BY

G. W. LUMMIS PATERSON

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"WIRING CALCULATIONS FOR ELECTRIC LIGHT AND POWER INSTALLATIONS," ETC., ETC.

WITH 139 *ILLUSTRATIONS*

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PREFACE

THE growing importance of electrical signalling in mining operations and the dearth of literature treating on this particular subject has induced the author to prepare this volume in the hope that it will fill a want felt by practical men engaged in the work.

The use of electricity for signalling purposes has now held a place in mining for a lengthy period, extending over the past fifty years. During this time it has progressed from being of the simplest possible description, suited to the leisurely methods incidental to mining at this early date, to the more complicated systems of the present day, the introduction of which is due chiefly to the constant efforts now being made to speed up the winding and haulage arrangements of a mine.

In preparing this volume, the author has endeavoured to carry out two objects, viz., to illustrate and describe such apparatus which, as the result of experience, has been found to give the best results in practical mining work, and further to indicate, by the aid of plans and diagrams, the most approved methods of installing the apparatus and maintaining the same in working order.

In following out this course, it has been necessary, in order to render the work as complete as possible, to

obtain assistance from a number of manufacturers, who have been good enough to supply various particulars concerning their patented and other electrical mine signalling apparatus, and to these firms the thanks of the author are due.

G. W. L. P.

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ELECTRIC MINE SIGNALLING INSTALLATIONS

CHAPTER I

INTRODUCTION

SOME system of signalling between different parts of a mine has been found indispensable from remote times.

In the more primitive methods, mechanical means are relied upon solely to transmit the signals. The most ancient and still the favourite form of mechanical mine signal gear is the *rapper* consisting of a hammer or drop weight which is lifted by a wire or rope and allowed to drop upon a loose metal plate. The signals are transmitted by giving a varying number of *raps* of the hammer, corresponding to a code of signals arranged for each particular case. This system is still largely used (and especially for shaft signalling) for the purpose of signalling over comparatively short distances, say, from 200 to 300 yards. When the distance exceeds this limit the difficulty of operating the system, due to the weight of the transmission rope and friction of the mechanism, becomes so pronounced that it is necessary to employ relays of men stationed at intermediate points to pass on the signals from the sending to the receiving stations. In consequence, the speed of

signalling is somewhat slow and mistakes are also liable to be made in the re-transmission of the signals at the intermediate stations. For these reasons, and also on account of the lesser wear and tear involved in their use, electric signals have now almost entirely superseded the various mechanical systems when signalling over long distances.

Owing to the rough nature of the work and the liability of the mechanism of the signalling apparatus to be affected by the presence of wet and dirt, etc., it is generally found necessary, in cases where electrical signalling is being adopted for mining purposes, to employ specially designed accessories, the ordinary types of keys, pushes, and bells, etc., not being equal to the task of working efficiently under the exacting conditions prevailing in mining work. The use of specially designed apparatus is particularly necessary in the case of fiery mines where sparking at the contacts of keys or pushes and bells is liable to cause an explosion of *fire-damp*, or inflammable gas, if this is present in sufficient quantity. In order to prevent danger arising from this source, the installation of electric signals in such mines in Great Britain, in addition to being subject to the rules in force in ordinary non-fiery mines, is further regulated by special Home Office Rules which specify the type of apparatus to be employed, and the manner of its installation, and, further, limits the voltage of signalling circuits underground in fiery mines to 25 volts. Where single stroke bells are used it is not particularly necessary—although desirable—to take special precautions to make the bells gas-tight as the circuit is never broken while the bell is being operated. Both trembling bells and keys or pushes,

however, must be, as sparking takes place, at the contacts which is quite capable of igniting any inflammable gas or fire-damp which may be present in explosive proportions. In such circumstances the containing box must be strong enough to withstand the explosion of the small amount of gas contained in it without fracture, or contact with the outside gas. The wiring, in mines of this description, must also be arranged so that any sparking due to accidental contacts between bare portions of the wires or terminals of the apparatus is avoided. In some mining installations the same line wires are used both for the purpose of telephoning and for bell signalling, but this practice is to be deprecated as there is a liability for a telephone call to be mistaken at the engine-house for a bell signal, with the possibility of the engine being started or stopped at a moment when such a proceeding is not wanted, with consequent risk of loss of life or serious damage to the mine equipment. Separate circuits are therefore to be recommended for both telephones and signal bells. When an electric light or power installation forms part of the equipment of a mine, no earth or ground returns for the system of conductors comprised in the signalling installation should be adopted, as there is considerable risk of the instruments being burned up or the signal operators receiving a dangerous, if not fatal shock, should any accident happen to the insulation, or if the earthing or grounding arrangements of the higher voltage light or power circuits become defective, as often happens.

The importance and efficiency of electrical mining signals has now been generally recognised by most of the principal mining countries of the world and special

rules have been elaborated regulating the construction and installation of the apparatus with a view to ensuring the greatest possible reliability and safety in operation. An abstract of the Rules and Regulations issued by the British Home Office relating to electric mining signals, together with the corresponding Rules of the American Bureau of Standards, is contained in an Appendix.

CHAPTER II

RINGING KEYS AND TAPPERS

CONTACT-MAKING devices, such as ringing keys and tappers, etc., which are used for the purpose of transmitting signals form a very important part of electrical mine signalling equipment. The primary essentials governing their design and construction are strength and simplicity. For use on dry roads underground, cabins, and engine-houses, hardwood mountings are quite admissible, but wherever wet or dampness, or much dust is present, the contacts should be enclosed in brass or iron watertight cases. If this requirement is not efficiently carried out, the contacts will, under such conditions, become encrusted with dirt rendering reliable signalling impossible, and if moisture is present they will quickly corrode owing to the electrolytic action set up by the current. For this last reason the contacts should always be mounted upon a separate ebonite or porcelain base and not direct on to wood or slate or similar material capable of absorbing moisture as sometimes is the case when the contacts are otherwise satisfactorily protected from damage by being fitted into a metal case. The *closed circuit* system of signalling is very rarely adopted in mining work and for the most part the contact-making devices appertaining to *open circuit* working are employed. These

may be either of two kinds, viz., (1) plain circuit closers similar in action to an ordinary bell push, and (2) Morse keys for return signalling.

Morse Ringing Key or Tapper.—Fig. 1 shows the simplest form of mining key or tapper which may be adapted for either sending only or for return signalling. It consists of an ordinary Morse key having the contacts mounted upon a polished hardwood block, forming the base of the key.

The key is composed of three contacts, viz., two metal stud contacts and a brass contact bar. The contact

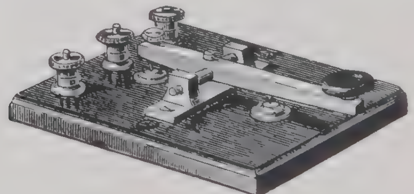


Fig. 1.

bar works on a steel pivot fixed into a brass bridge, the three contacts being insulated from each other through the medium of the hardwood base. The Morse key, as illustrated in Fig. 1, may be adapted for use either as a plain circuit closer, for return signalling, or for breaking the circuit, in closed circuit working. When arranged for return signalling the back stud contact is connected to the *bell* or *return* line terminal, the bar and bridge to the *line* and the front stud contact to the carbon or positive pole of the sending battery. This arrangement of the connections is shown in Fig. 2. Under normal conditions the back end of the contact bar rests upon the *return* contact stud, being held in that

position through the medium of a flat spring fixed to the underside of the brass contact bar. The key is then in a condition for receiving a signal, the current, arriving from the distant sending station, passing from the line by way of the contact bar and bridge to the return terminal and through the bell, or other signal alarm device, arranged in circuit with the return line wire or earth. In sending a signal, the front end of the contact bar is depressed by means of the push

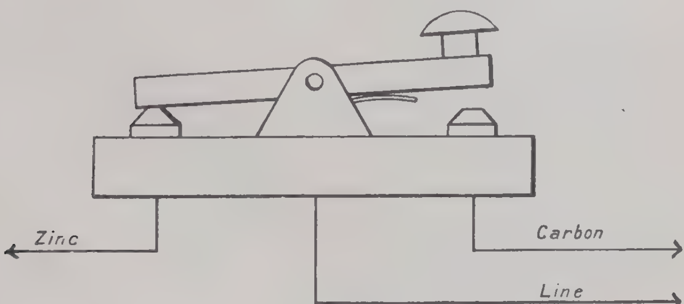


FIG. 2.

button or knob fixed thereon and shown in the illustrations (Figs. 1 and 2). This button or knob is made of ebonite or other insulating material to obviate any chance of the operator receiving a shock in transmitting a signal, due to the self-induction of the circuit should the insulation be in a faulty condition when sending a signal. The action of depressing the contact bar performs a double operation, viz., it disconnects the return stud contact and terminal from the line and thereby cuts out the home receiving instrument, and at the same time it brings the front end of the contact bar into contact with the front contact stud and thus puts

the carbon pole of the battery into electrical connection with the line, thus enabling a signal to be sent to the distant receiving station. When employed as a plain circuit closer the back contact stud and terminal remains disconnected ; the line being connected to the contact bar and the front contact stud to the carbon or positive pole of the battery as before. When used in connection with closed circuit working, the office of the key is to enable the circuit to be conveniently broken, and this is effected by connecting one line wire to the

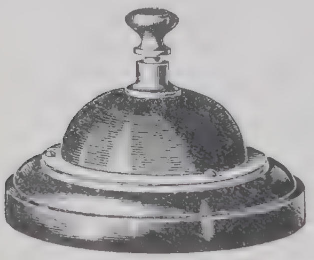


FIG. 3.

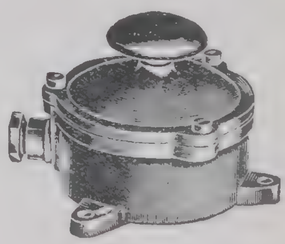


FIG. 4.

back contact stud and the other line wire to the contact bar. Pressure on the push button at the forward end of the contact bar then lifts the other end and breaks the circuit at the back contact stud. To ensure reliable working the tapping contacts should be tipped with platinum and it is best not to rely entirely upon the pivot to make efficient contact between the contact bar and the bridge, but to see that these are connected together with a *pigtail* of flexible braided copper cord.

Plunger Ringing Key or Tapper.—The mechanism of the Morse key, as illustrated in Fig. 1, is shown as being mounted upon a hardwood block. This type of key is

only suitable for use in dry places, and as the contacts are not enclosed it is also precluded from use in places where much dust is present. When required for working under these conditions the contacts should be entirely enclosed in a strong metal case or cover. Fig. 3 shows a common form of enclosed mining key or tapper. The tapper is similar in principle and action to the ordinary form of Morse key (Fig. 1). It is provided with three contacts, either two or three of which may be utilised according as the tapper is to be used for sending only, or for both sending and receiving signals. The contacts are mounted upon an insulating slab of ebonite. The base itself may be either of teak or brass or iron according to the nature of the situation in which the tapper is to be fixed. The contacts are entirely covered by a brass or gun-metal case. Through the centre of the cover projects a plunger which, when depressed, forces the contacts together and closes the circuit. Neither this type of tapper nor the preceding form (Fig. 1) is suitable for use in fiery mines owing to the sparking which occurs at the contacts when the circuit is broken.

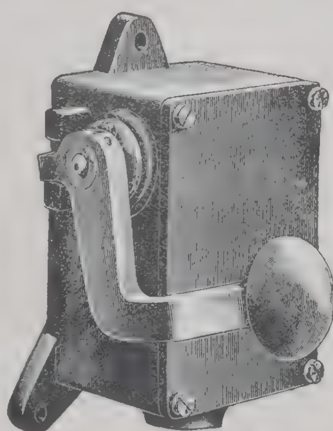


FIG. 5.

Gas and Watertight Ringing Keys or Tappers.—Figs. 4 and 5 illustrate two popular forms of gas and

watertight ringing keys. Fig. 4 is actuated by means of a plunger and the contacts are contained in an iron case. The conductors are led into the case through a stuffing-box or gland which ensures a perfectly water-tight and gastight joint and prevents the access of moisture to the contacts. In the ringing key illustrated in Fig. 5 the contacts are operated by means of a lever fixed to a spindle which works in bearings formed in the sides of the iron containing case. A stuffing-box is

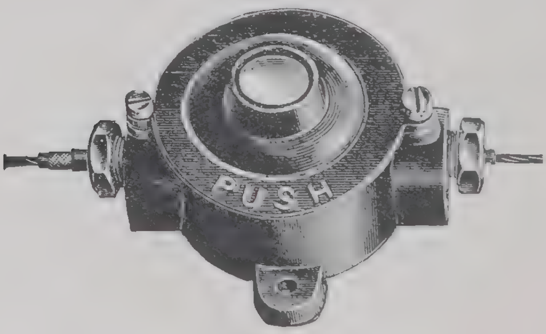


FIG. 6.

provided for leading in the conductors. It will be noted that the plunger keys illustrated in Figs. 4 and 5 are provided with projecting push buttons. Although these two forms of keys have had an extensive application and have given general satisfaction in mining work, it has occasionally happened that accidental contacts have been caused by leaning against the push. This risk, appertaining to this particular kind of key, has been recognised by the British Home Office, and rule 16 (*b*) stipulates that " contact-makers shall be so constructed as to prevent the accidental closing of the

circuit." This requirement can be satisfied either by fixing the ringing keys inside a wood frame or box the sides of which project beyond the plunger of the key, or the form of key shown in Fig. 6 may be used. This pattern of ringing key consists of a cast-iron gas and watertight case containing the necessary contacts

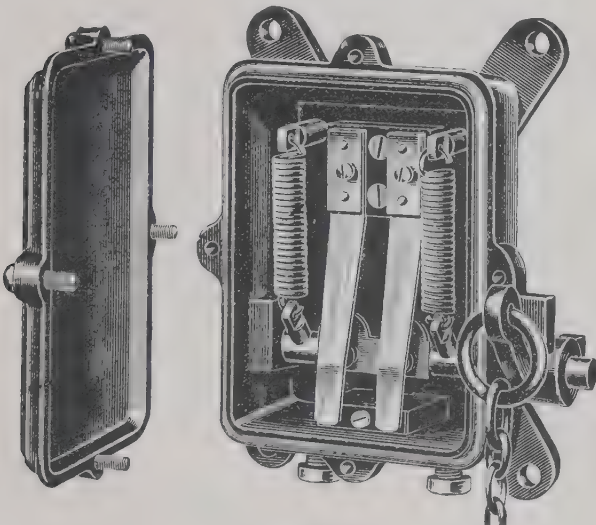


FIG. 7.

which are mounted on an insulating base of ebonite. The push button is fitted into a recess and remains quite gas and watertight under ordinary working conditions, while it is free from any chance of accidental contacts being made.

Gas and Watertight Bell-Pull Ringing Keys.—In some instances it is not always possible or convenient to fix the ringing keys at the correct height to enable the

plunger to be operated direct by hand and in such circumstances a *pull* tapper is used. An efficient form of this kind of ringing key is shown in Fig. 7. The contacts, to which the line wires are connected, are formed of heavy German silver springs which are mounted upon an ebonite base and enclosed in a cast-iron case. The contacts are actuated by means of a horizontal spindle which works in bearings formed in the sides of the metal containing case. This spindle is held in the "off" position by means of two strong spiral springs. The case is entirely closed up with a screw-on iron cover, the joint being rendered gas and watertight by means of a rubber washer or gasket. A leading-in gland or stuffing-box is provided for the conductors. This type of tapper may be fixed at any desired height and is operated by means of a chain attached to a lever which is fixed to the end of the contact spindle which projects through the side of the case. On the chain being pulled a strong rubbing contact is made with the German silver contact springs, and the circuit closed by a metal bar fixed to but insulated from the spindle. Fig. 8 shows another form of the pull tapper in which the contacts are actuated

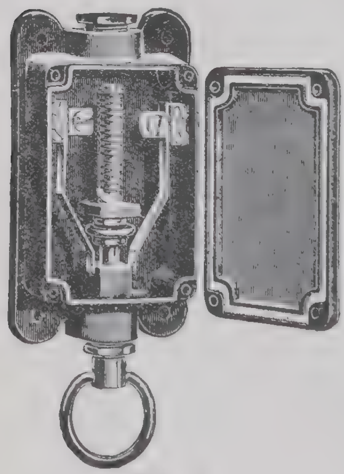


Fig. 8.

by a vertical rod sliding in a stuffing-box. The spring contacts, which are fixed to an ebonite base, are normally separated from each other ; when the plunger is pulled, contact is made through a brass ring which is insulated from the plunger and which bridges across the contacts. The helical spring returns the plunger to the normal or " off " position. It will be noted that in both of these forms of pull tappers it is not possible for accidental contacts to be made by a person leaning against them, and that they thus comply with the latest practice in this respect.

CHAPTER III

ELECTRIC MINING BELLS, SIGNAL ALARMS AND RELAYS

THE necessity of ensuring that a clear and audible signal is produced at all times calls for a bell, or other signal device, of the best possible design and construction. The special features to be looked for in a mining bell are as follows :—

(1) General strength of construction, to enable the bell to resist the rough usage it will be subjected to in daily work.

(2) Large electro-magnets, so that there may be an ample reserve of power.

(3) That the design embodies adequate provision that the various adjustments will not be altered or interfered with by changes of temperature or vibration.

The bell gongs should be large to ensure that a loud and unmistakable signal is produced. Gongs of less than 6 inches diameter are not admissible and 8-inch or 9-inch are preferable, while in exceptionally noisy places such as haulage engine houses it may be necessary to provide bells with 11-inch or 12-inch gongs to ensure that a reliable signal is received.

Types of Electric Bells.—The types of electric bells commonly used in connection with mine signalling may be enumerated as follows : *Trembling Bells*, *Single-Stroke Bells*, *Shunt Bells*, *Differential Bells*.

The Trembling Electric Bell.—When first used for mining work the trembling bell did not give satisfaction

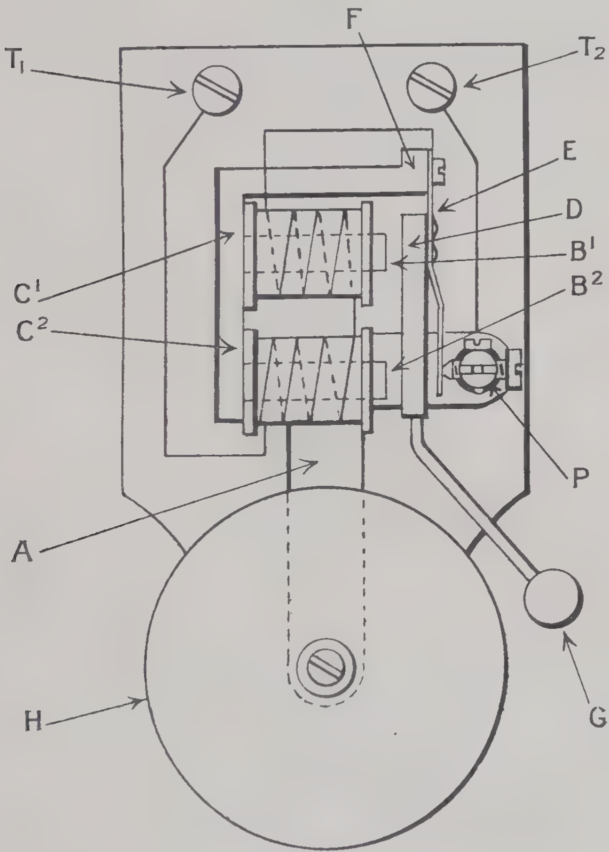


FIG. 9.

in a number of important particulars and the single-stroke bell was invariably used, but the design and

construction has now been made to conform with the modern conditions required in mining work and the trembling bell is now again in use.

The construction of this type of bell is shown in Fig. 9. It consists of a soft iron casting, A, provided with two round soft wrought-iron cores, B^1, B^2, on which the magnetising coils, C^1, C^2, are fitted. These magnetising coils consist of two boxwood bobbins or spools wound with silk-covered wire and are held in

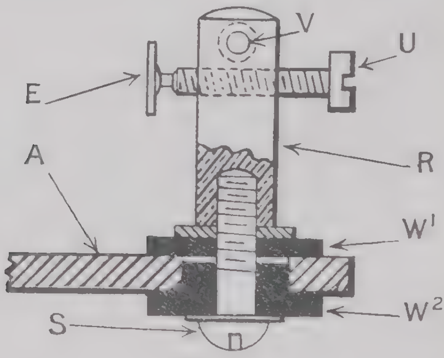


FIG. 10.

place on the cores by friction only. The armature, D, is a piece of flat soft wrought-iron to which the spring, E, made of German silver, is screwed or riveted. One end of this spring is fixed to a projection, F, on the cast-iron base plate, A, and the other end is bent away from the armature slightly. The free end of the armature is provided with an iron wire and brass ball, G, this latter forming the hammer which strikes the gong, H. The construction of the contact pillar, P, is shown in detail in Figs. 10 and 11. The pillar, P

(Fig. 9), consists of a brass rod, R, tapped at one end to take a metal thread screw, S, by means of which it is fixed to the soft cast-iron base plate, A, being insulated from the latter by the insulating washer, W^1, and bush, W^2. The contact screw, U, passes through the side of the pillar and is locked in position by the pinching screw, V, the top of the pillar being slit for this purpose. A small piece of platinum wire or foil is riveted or soldered on to the end of the contact screw,

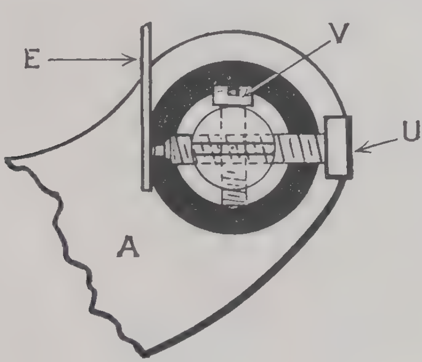


FIG. 11.

U, and presses upon a similar piece of platinum fixed to the end of the armature spring, E. The armature is normally kept at a slight distance away from the ends of the soft iron cores, its distance from the latter being adjusted by means of the contact screw. One of the free ends of the magnetising coils is connected to the terminal, T^1, and the other end to the armature spring, which is not insulated from the cast-iron frame of the bell. The other terminal, T^2, is connected to the contact pillar. The mechanism of the bell is mounted

upon either a metal or wood base, and it should preferably be provided with a suitable cover to exclude dust and dirt and prevent damage to the mechanism. The two terminals, T^1, T^2 are insulated from each other by the wood base to which they are fixed, or by means of insulating washers if a metal base is employed.

Action of Trembling or Vibrating Bell.—The action of the trembling or vibrating bell will be understood by reference to Fig. 12. In circuit with the bell is connected a battery, and also a push by means of insulated line wires. When the button of the push is pressed down the two German silver or hard brass springs to which the two ends of the line wires are connected are brought into contact, thus completing the circuit. A current then flows from the carbon pole of the battery through the line wires and push to the terminal, T^1, of the bell. The current then flows through the magnetising coils of the bell and by way of the armature spring to the platinum contact on the contact screw. Passing thence through the contact pillar it flows to the terminal, T^2, of the bell, and so on to the zinc pole of the battery, thus forming a complete circuit. While the current is passing through the magnetising coils of the bell they magnetise the iron cores of the electro-magnet, the poles of which attract the iron armature, causing it to move towards them. In doing so, however, the circuit of the bell is broken by the armature spring leaving the contact pillar. As the cores of the electro-magnet are of soft iron, the instant the current ceases to flow all trace of magnetism disappears and in consequence the armature, under the influence of its spring, returns to its original position. The circuit through the bell being again completed by this action,

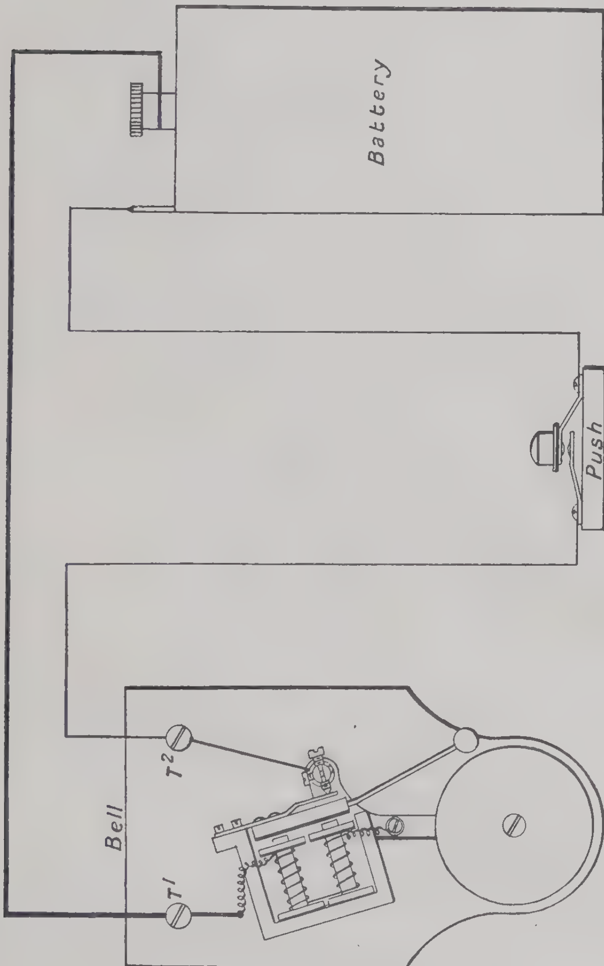


FIG. 12.

the armature is again attracted, this cycle of operations being repeated so long as the push is pressed. A vibratory motion is thus produced, which being transmitted through the medium of the armature wire or rod to the hammer, keeps up a continuous ringing of the bell.

Adjustment of Trembling Bell.—In adjusting a trembling bell the object is to cause the bell to give out the maximum sound. This is accomplished by suitably adjusting the position of the armature in its relation to the cores of the electro-magnet and the adjusting screw of the contact pillar. The correct adjustment is attained when the hammer is in contact with the edge of the gong and the face of the armature is separated from the ends of the magnet cores by the thickness of a post card. In adjusting the bell it will be necessary to bend the hammer rod more or less, according to circumstances, until this position is attained. The platinum point or tip of the contact screw should then be separated from the platinum contact on the armature spring by a distance of about $\frac{1}{32}$ inch. The contact screw must be screwed out or in, while the armature and hammer is held in position against the magnet cores and gong, until it is correctly adjusted, when it must be locked in position by the pinching screw provided for the purpose. If the armature in this particular type of bell is allowed to strike the ends of the magnet cores an unpleasant tapping or chattering sound will be produced while the bell is ringing. If the contact screw is screwed in too far the circuit will not be broken when the current flows through the magnetising coils and the armature will be held motionless against the ends of the magnet cores and no sound will be produced. On

the other hand, if screwed out too far only a feeble intermittent ring will result since the hammer will not reach and strike the gong with much force. The strength of the armature spring also has a considerable influence on the ringing properties of a bell, and a screw is sometimes fitted to the base-plate for the purpose of adjusting its tension. If too weak it is liable to make uncertain contact with the contact screw, and if too strong it will require excessive battery power to operate the bell.

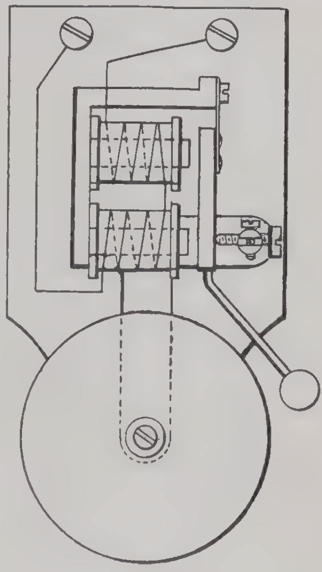


FIG. 13.

Single-Stroke Electric Bell.—Although it is possible to devise a code of signals, consisting of a pre-arranged number of rings, in connection with an ordinary trembling bell, a more perfect device for this purpose, as being better adapted for producing a clearer and more definite sound, is the *single-stroke* bell. The construction of this type of bell is illustrated in Fig. 13. As will be seen, it is similar in construction in all respects to the ordinary trembling bell except in one particular in that all contacts in the internal circuit of the bell are eliminated. This fact makes for greater reliability and causes this type of bell to be used in preference

to the trembling bell wherever it is important that definite signals are essential. Although the same form of contact pillar still forms part of the equipment of the bell, this is minus the platinum contacts, and furthermore the pillar is not insulated from the frame of the bell. Its sole purpose is to serve for adjusting, mechanically, the distance of the armature from the ends of the magnet cores or poles and the length of the stroke of the hammer of the bell. In some instances, single-stroke bells are provided with the same form of armature spring as used for trembling bells, including the extension used for the contact-making device. This pattern is not to be recommended, however, as a vibratory motion of the hammer is liable to be occasioned, which may continue after the circuit has been broken, giving rise to false signals. The two ends of the magnetising coils are each connected to insulated terminals and these form the only electrical connections appertaining to the bell.

Action of Single-stroke Bell.—If a single-stroke bell be substituted for the trembling bell and arranged in circuit with a battery and push, as illustrated in Fig. 12, on pressing the push the electro-magnet of the bell will be energised and will forcibly draw up the armature, striking the hammer against the gong while so doing and retaining it there so long as the circuit is closed. On the circuit being broken the armature, under the influence of its spring, will return to its normal position, *i.e.*, resting against the screw stop. Thus a single stroke or ring of the bell is given each time the push is pressed.

Adjustment of Single-stroke Bell.—It has been mentioned that in adjusting a trembling bell the

clearest sound is produced when, at the moment the hammer is striking the gong, the armature is separated from the ends of the magnet cores by a small space. In the case of a single-stroke bell this is, however, a positive disadvantage. The armature in this type of bell should be adjusted so that when it is in contact with the magnet poles the hammer is just clear of the gong. The elasticity of the hammer rod, combined with the momentum of the hammer causes the latter, at the end of the stroke, to strike the gong and immediately rebound, giving out a clear ring. If the hammer strikes the gong before the armature reaches the ends of the magnet cores a muffled sound only will be produced owing to the hammer preventing the vibration of the gong and the consequent production of sound waves. The purpose of the stop screw is to adjust the distance of the armature from the magnet poles and the length of the stroke, which varies in accordance with the size of the gong and the amount of battery power at disposal.

The Shunt Bell.—It is often found desirable to arrange two or more bells in series with one another in the same circuit. If single-stroke bells are employed, no difficulty will be experienced, but if ordinary trembling bells are used the ringing will not be satisfactory. The reason for this is the fact that it is not possible to adjust the bells so that they all break contact at the same instant, consequently the ringing is very erratic and unreliable. To overcome this difficulty, under these circumstances, when the single ring of a single-stroke bell is objectionable, the *shunt* or *short-circuiting bell* was designed. The construction and arrangement of this type of bell is shown in Fig. 14.

The bell is provided with a stop screw and pillars which answer the same purpose of adjusting the position of the armature in its relation to the magnet cores as in the case of a single-stroke bell, but, in addition, a contact pillar, P, is also fitted to the bell. One end of the magnetising coils is connected to the terminal, T^1, and also to the contact pillar, P, which is insulated from the frame of the bell. The other end of the coil is connected to the frame of the bell which is further in electrical connection with the terminal, T^2. The armature is fitted with a contact spring, R, tipped with platinum. It will be noted that the circuit through the magnetising coils is not broken at the contact pillar by the vibrations of the armature, but that the forward motion of the latter shunts or short circuits the coils.

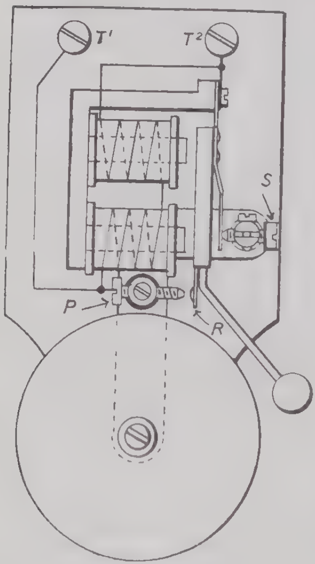


FIG. 14.

Action of Shunt Bell.—The action of the shunt bell is briefly as follows: On the current flowing through the magnetising coils, the armature is attracted and the spring, R, makes contact with the contact screw of the pillar, P. This has the effect of short-circuiting the magnetising coils since an alternative

path is made for the current through the armature from one terminal to the other. As this short circuit has practically a negligible resistance as compared with the magnetising coils the main current is shunted from the coils and they lose their magnetising power. In consequence, the armature is no longer attracted and falls back against the stop screw and the same action is repeated so long as the circuit is closed. From this it will be seen that no matter how many bells are arranged in series, the circuit is never broken so long as the operating push is pressed. Owing to this fact the sparking at the contacts is much less than is the case with ordinary trembling bells and the platinum contacts last longer.

The Differential Bell.—While an ordinary trembling bell is ringing a spark is produced at the contacts with every vibration of the armature. This sparking has a very detrimental effect on the contacts of the bell, burning and wearing them away rapidly. This is particularly the case if a large bell and battery is used, or if a bell is operated on a light or power circuit, as sometimes happens. This sparking is also liable to cause an explosion if the bell is fixed in an atmosphere charged with inflammable gas such as obtains in a fiery mine, and numerous accidents have been traced to this cause. Many remedies have been devised to overcome this sparking at the contacts of a bell. As the contacts are entirely absent in a single-stroke bell no sparking can possibly occur in this type of bell, and to this fact is due its great popularity in mining work. A single-stroke bell is not, however, well adapted for giving an alarm in case of accidents and for other emergency purposes for which a continuous-ringing bell is more

suited. Under these circumstances and also for series working the *differential* bell gives the most satisfactory

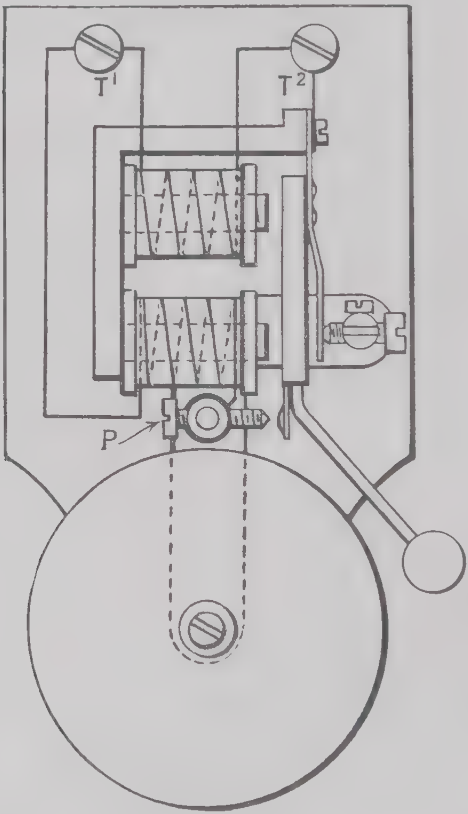


Fig. 15.

results. The construction and arrangement of the connections of a differential bell are shown in Fig. 15. As will be seen, as regards its mechanical construction

and arrangement of parts, it is identical with the shunt bell (Fig. 14). It differs from the shunt bell only in the arrangement of its magnetising coils, and their connection to the circuit. These coils consist of two entirely separate windings or coils which may be single, as shown, or double wound. These two coils are wound in opposite directions on the magnet cores, so that when current flows through both at the same time the magnetising action of one is neutralised by that of the other. The two ends of one of the coils are connected direct across the two terminals, T^1, T^2, one end of the other coil is connected to the terminal, T^1, and the other end to the insulated contact pillar, P. The other terminal, T^2, is also connected to the metal frame of the bell.

Action of Differential Bell.—On closing the circuit, through a push or other device, the coil or winding on the upper limb of the electro-magnet is energised and the armature is attracted, thereby striking the gong. At the same time the contact on the armature makes contact with the contact screw and pillar, P. This action closes the circuit through the winding on the lower limb of the electro-magnet which in turn neutralises the magnetism imparted by that of the upper winding, and the armature being no longer attracted reverts to its former position and the action is repeated continuously so long as the circuit remains closed.

It will be noted that the upper winding or coil is so connected that it remains always in circuit so long as the push is pressed, the lower winding only being subject to an intermittent current. It is, therefore, obvious that the full current is never broken at the

opening of the neutralising circuit as the alternative circuit through the upper winding always remains closed. This device entirely obviates any sparking at the contacts of the bell and undoubtedly renders this type of bell most suitable for use in fiery mines, even though it has the additional safeguard of its mechanism being inclosed in a gastight casing. The differential bell is also to be preferred, in place of the shunt bell, for series working, as, unlike the shunt bell, it does not short circuit the battery while ringing, one coil of the differential bell at least being in circuit with the battery so long as the circuit remains closed.

Fig. 16.

Classification of Electric Mining Bells. — According to the manner in which the mechanism is mounted and protected from damage electric bells, as adapted for mine signal installations, may be classified as follows: *Wood-Box Bells, Block-Signal Bells, Waterproof Bells, Gas and Watertight Bells, Magneto Bells.*

Wood-Box Bells. —The wood-box bell (Fig. 16) is most extensively used for ordinary purposes, being well adapted for a dry situation and general interior use. When required for mine signal purposes the mechanism should be mounted upon a polished teak or oak wood base-board and covered with a teak or oak box. The

base-board should be provided with brass screw cups, to prevent splitting of the board when fixing, and the wood box glued and screwed together. The magnetising coils should be formed of silk-covered copper wire, preferably soaked in paraffin wax or well shellacked to obviate any risk of corrosion due to the presence of moisture in the atmosphere. The terminals should be large and massive and well lacquered. The internal wiring of the bell should be exposed and all connections

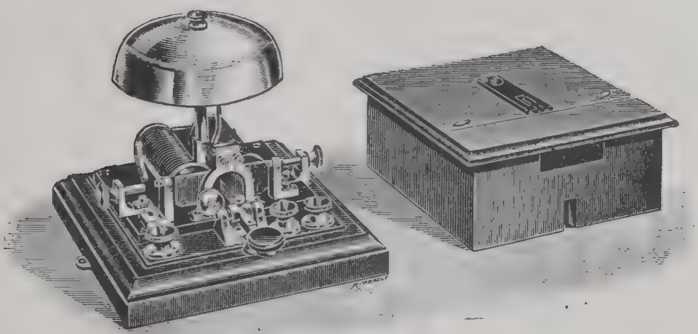


FIG. 17.

made on the front of the base-board. A frequent source of trouble with electric bells is the breakage of connecting wires at the back of the base-board. The bells being fixed direct on to a wall leads to moisture collecting at the back of the board, with consequent corrosion of the connections, and these being concealed from view, the fault is often difficult to trace.

Block-Signal Bells.—In places where the situation is dry and not much dust is present, as is the case in downcast haulage roads, engine planes, and engine

houses both on the surface and underground, no valid reason exists why the ordinary type of wood-box bell (Fig. 16) may not be used for signalling purposes. In a large number of cases, however, a strong preference is given for the *block-signal bell*, as illustrated in Fig. 17. It will be noticed that a Morse ringing key forms

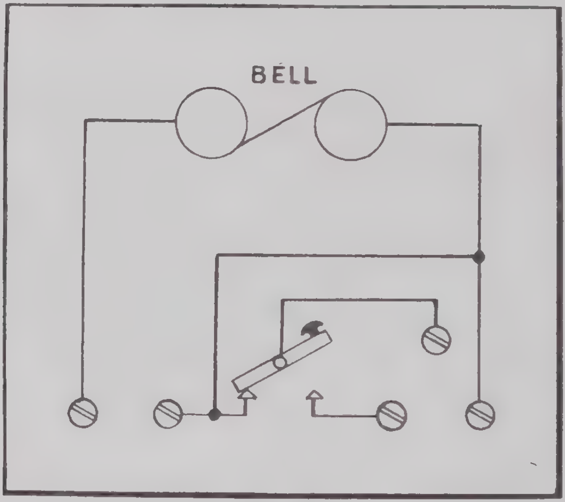


FIG. 18.

part of the equipment of the bell, being combined on the same base-plate. The bell consists of a brass foundation-plate on which is fixed a large size electro-magnet, the bobbins or spools of which are provided with brass flanges. The magnetising coils are of silk-covered copper wire, well varnished to resist dampness. An iron armature swings in front of the pole pieces of the electro-magnet being suspended on pivots screwed into

two brass brackets fixed to the base-plate. The brass foundation-plate is fixed on to an ebonite insulating slab which in turn is fixed on to a polished teak or oak wood base. The mechanism is arranged to work while the base is normally in a horizontal position. An upright brass stalk, which is fixed on to the base-plate, carries the gong. The bell hammer and stem which is fixed to the armature is controlled by gravity only, no spring tension being employed as in ordinary bells. The position of the armature, in its relation to the pole pieces of the electro-magnet, is adjusted by means of a screw and lock nut. The Morse key is of the ordinary pattern, and is fixed to the ebonite insulating slab. The whole of the mechanism, excluding the gong and hammer, is enclosed in a polished teak or oak wood box. The box is secured in position by means of two brass thumb-screws, seen at the sides of the bell in the illustration. The bell gong and hammer projects through the top of the box, an ebonite slide being provided to exclude dust as much as possible. It will be noted that the particular form of bell shown in the illustration has three terminals only, the Morse key and bell being in permanent electrical connection together. An alternative method of arranging the connections of these bells is to enable

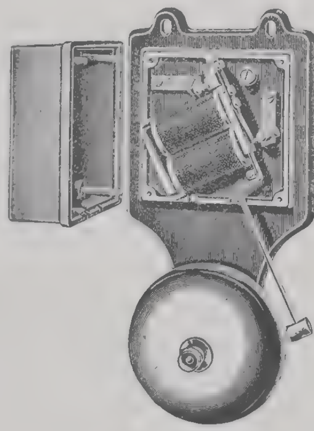


FIG. 19.

either the bell or the Morse key to be used independently, and for some purposes this is preferable. The bell is then provided with five terminals, the internal connections of the bell and Morse key being arranged as shown in Fig. 18.

Waterproof Bells.—For use in places subject to wet and dampness, a waterproof bell is a necessity, the ordinary form of electric bell with wood base and cover being, of course, useless as the different parts soon corrode and perish. A number of different arrangements are in use for preventing the access of water to the mechanism and that illustrated in Fig. 19 is a good example of waterproof bell of simple design and construction. The base and cover are of cast-iron; the cover being fixed by means of four screws and a rubber washer or gasket ensures a watertight joint between the base and cover. The magnetising coils are of silk-covered copper wire well varnished. The armature and hammer stem are copper plated and nickel plated to resist dampness.

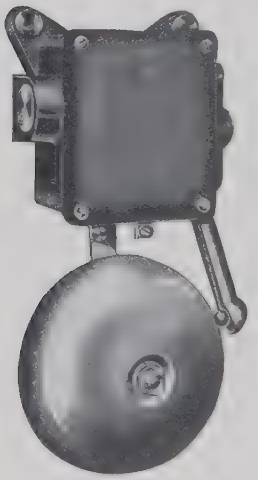


FIG. 20.

Gas and Watertight Electric Bells.—Having proved its superior efficiency in working under normal conditions in mining, the electric signalling system has now been extended into all parts of the mine and frequently into positions where the presence of gas and water

cannot always be avoided. To enable this extension to be successfully carried out special types of ringing keys, bells and other accessories have been designed to suit the special and oftentimes severe conditions of working. In the presence of dampness only a water tight bell of the kind illustrated in Fig. 19, will give satisfactory service. Where gas or extremely wet conditions prevail a totally enclosed bell is the only form that can be employed. A number of different designs are available for this purpose; Fig. 20 shows an efficient pattern which is now being extensively adopted for mining work. The working parts are enclosed in a gas and watertight cast-iron case which is enamelled to resist the effects of the dampness. The hammer rod is connected to the armature by means of a ball joint embedded in vaseline. This renders the connection completely gas and watertight, and at the same time gives a very easy movement to the hammer. Consequently an exceptionally loud sound is obtained which is especially inportant in mine signalling. A protecting shield covers the hammer and a cable gland is provided for leading in the conductors.

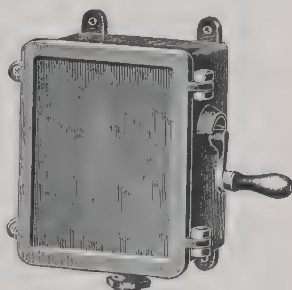


FIG. 21.

Magneto Bells and Generators for Mine Signal Installations.—For long-distance signalling, both under ground and on the surface, the magneto bell and generator offers many important advantages over a battery-operated system if they can be conveniently

adopted. A properly constructed magneto generator is not very liable to develop faults and requires very little attention. The magneto bell, while possessing all the advantages of the trembling or vibrating bell, is free from sparking and other troubles at the contacts, and is, therefore, well suited for underground working. These advantages have been so well recognised that bells and generators are now obtainable which have been specially designed for mine signalling purposes. Fig. 21 shows a generator and Fig. 22 a magneto bell of this description. The working parts of both these appliances are contained in cast-iron water and gas-tight cases which are fitted with cable glands and other accessories which have now become standard practice in the design of this class of apparatus in order to secure efficiency and durability under working conditions. The hammer rod of the magneto bell is connected to the armature through a vaseline compartment.

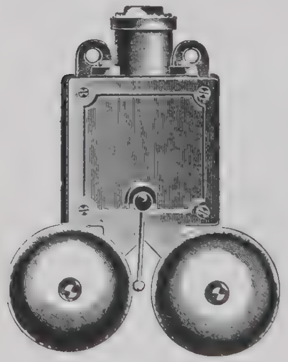


FIG. 22.

Electric Hooters.—The electric hooter is a comparatively new innovation in regard to electric signalling, but nevertheless it already has an extensive application for mining work in place of a bell in cases where either a louder or a more distinctive tone is required. The type of hooter best adapted for mining purposes is illustrated in Fig. 23. The hooter consists essentially of a metal diaphragm which is thrown into vibration by an

electro-magnet actuating a contact-making and breaking device. The mechanism is enclosed in a gas and watertight cast-iron case which is provided with a cable inlet for leading in the cable and making all gas and watertight. These hooters emit a sound of a deep and penetrating nature and work with a remarkably small current.

FIG. 23.

Connecting Bells in Circuit.—In cases where a number of bells are to be operated simultaneously in the same circuit, it is necessary to connect them to the circuit in such a manner that the working of each bell is not interfered with by others in the same circuit. There are two principal methods of connecting bells in circuit, viz., in *series* and in *parallel*. It is possible to employ various combinations of these two methods, but as these are not often required in practical work they need not here be taken into consideration. In regard to the question as to which of these two methods it is best to employ, this depends entirely upon circumstances and individual requirements, and no general rule can be given in order to determine when either system will be most suitable. The parallel system requires bells preferably of high resistance, whereas the series system is best worked with low resistance bells.

Bells in Series.—The method of arranging bells in series is shown in the diagram (Fig. 24). It will be noted that the circuit is arranged so that the current

flowing from the positive pole of the battery, B, when the push, P, is pressed, passes through each of the bells in turn and returns to the zinc pole of the battery.

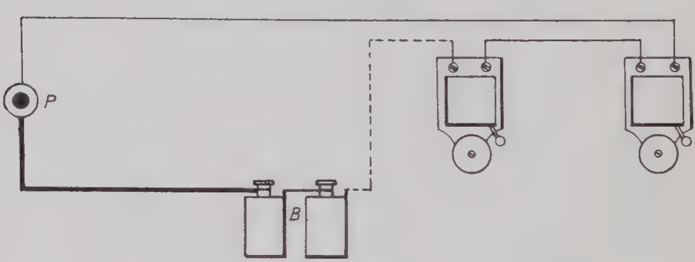


FIG. 24.

When the bells are arranged in series the current required to work them is only that required to work one bell, but the voltage of the battery must be high on account of the high resistance of the circuit. This

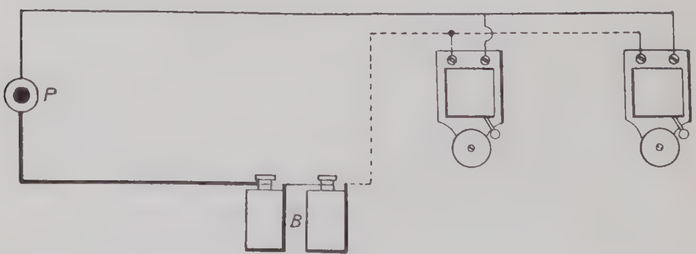


FIG. 25.

evidently calls for a battery composed of small-sized cells, but comparatively large in number, to generate the necessary voltage to overcome the high resistance of the circuit. Trembling bells will not work satisfac-

torily in series; the best results are obtained with either single-stroke, shunt, or differential bells.

Bells in Parallel.—Fig. 25 shows the method of arranging bells in parallel for simultaneous ringing. On the button of the push, P, being pressed the current flows from the positive pole of the battery, B, through the push, P, and through the line wire to the first bell where it divides, part passing through the first bell, and part through the other bell, and so on to the negative pole of the battery. When bells are arranged in parallel in this manner, it is necessary, in order to secure satisfactory operation, to select only bells which have the same resistance as nearly as possible, otherwise the sounds emitted by the bells will not be uniform in intensity, those having the higher resistance ringing feebly as compared with the others. The parallel system requires the battery voltage to be as low as is necessary to work a single bell, but the current required for the whole circuit is the sum of the current required for each bell. This points to a battery composed of a small number of large size cells to provide the necessary strength of current.

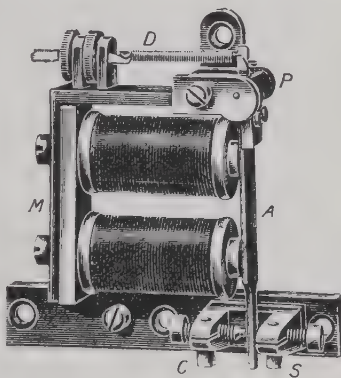


FIG. 26.

Electric Relays.—A relay is an electro-magnetic device for bringing into action an electrically indepen-

dent piece of apparatus. The principle of its construction and action will be understood by reference to Fig. 26, which shows the mechanism only of the relay. The relay consists essentially of an electro-magnet, M, a soft iron armature, A, and local contact pillar, C. The armature is provided with a platinum-tipped

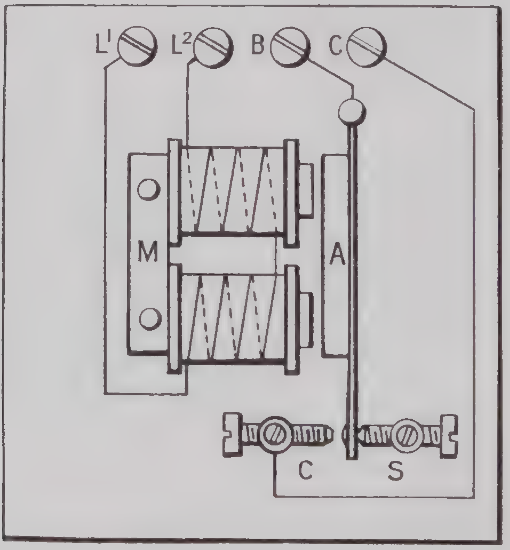


Fig. 27.

contact at its lower end; the upper end being pivoted at P. The armature, in a normal condition, rests against the stop, S, its pressure against the latter being regulated and adjusted by means of the spiral spring, D. The armature, A, is very light in weight, and extremely sensitive so that it is attracted by the electro-magnet, M, when a minute current of a few milleamperes only

flows through the magnetising coils of the latter. The arrangement of the internal connections of a relay is shown diagrammatically in Fig. 27. It will be seen that the relay is provided with four insulated terminals, to two of which the two ends of the magnetising coils are connected while the other pair of terminals are connected, one to the local contact pillar, C, and the other to the frame and armature. The stop, S, together with the local contact pillar, C, are entirely insulated from the frame and armature of the relay

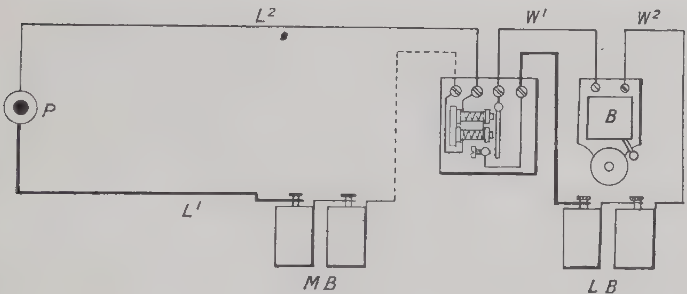


FIG. 28.

under normal conditions. The purpose of the stop, S, is purely mechanical, its object being to adjust the distance of the armature from the poles of the electro-magnet, M. It will be noted that this arrangement of the connections constitutes two entirely independent circuits; that through the magnetising coils appertaining to what is known as the *main* or *relay* circuit, while that through the armature, A, and contact pillar, C, forms part of a *local* circuit which also contains the signal bell and local battery.

The purpose of a relay is to obviate the use of an

excessively large battery in cases where a signal is to be transmitted over a comparatively long distance ; or over a short distance where excessively wet conditions prevail so that considerable leakage results and it is necessary to keep the voltage of the signalling circuit as low as possible. In Fig. 28 the circuit of a simple form of relay is shown. The relay is connected in circuit with the line wires, L^1, L^2, and is operated by means of the main battery, MB, when the circuit is closed by the push, P.

The local circuit is composed of the signal bell, B, local battery, LB, and insulated connecting wires, W^1, W^2. The main battery, MB, which actuates the relay only, may be composed of any convenient number of cells according to the length of the circuit. The local battery, LB, which actually rings the bell may be composed of just so many cells as may be necessary in order to obtain a reliable ring, since the battery will only have to work through a few feet of connecting wire.

Action of Electric Relay.—When the push or ringing key, P, is pressed, the current from the main battery, MB, energises the electro-magnet of the relay, and the armature being attracted the platinum-tipped contact fitted on to its end comes into contact with the screw of the contact pillar. These contacts close the local circuit containing the bell, B, and the local battery, LB, causing the bell to ring every time that the push, P, is pressed. The relay resembles a second push or ringing key placed near to the bell, but controlled by electric current from a distance instead of being depressed by hand. Its advantages consist in it needing but a very weak current to actuate the

armature, A, and contact mechanism, much less than would be required to ring the smallest bell direct. The relay may then be set as near to the bell as possible, and the line wires connecting it to the push or ringing key and main battery may be of a very great length without interfering in any way with the loudness of the ring given by the signal bell, since this is actuated by a separate local battery.

Wood-Box Bell Relays.—The mechanism of a bell relay being of a somewhat delicate character necessi-

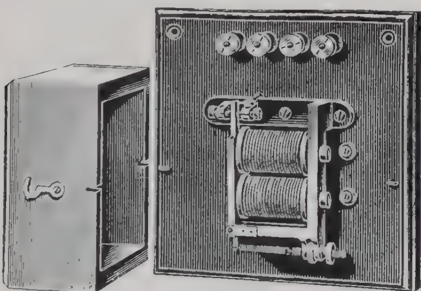


FIG. 29.

tates its being enclosed in a case of some kind in order to prevent its action being interfered with by the presence of dust and damp, etc. For use in dry situations a case made of polished teak or oak or other hardwood will give satisfactory service. Fig. 29 shows a wood-box relay of the kind referred to.

Gas and Watertight Bell Relay.—In places where wet or damp or other unfavourable conditions exist, it is necessary to enclose the relay mechanism in a gas and watertight case. Fig. 30 shows an approved form of this kind of relay. The case consists of a solid iron

casting provided with a screw on iron cover, the joint being rendered watertight by means of a rubber washer. The box is fitted with gun-metal glands for leading in the cable.

Electrical Resistance of Mining Bells, Signal Alarms and Bell Relays.—The electrical resistance of mining bells, hooters, and other signalling devices must be adjusted to suit the conditions of working, having regard to the size of the bells and the method of

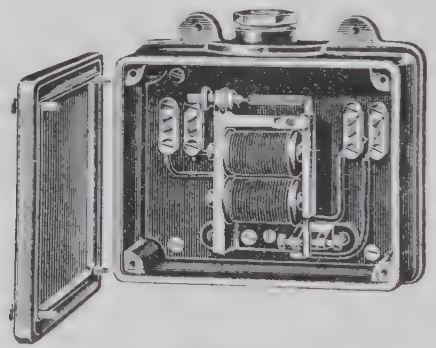


Fig. 30.

arranging them in circuit (whether in series or in parallel) and also on the resistance of the line circuit. This latter is again affected by the length, gauge and material composing the line wires of the circuit. In cases where a bell is required to work over a comparatively short distance, say not more than half a mile, or where a number of bells are arranged to work in series, the magnet coils may be wound with somewhat thick copper wire having a comparatively small resistance. On the other hand, where the distance over which the

signal is to be transmitted is greater than that referred to, or when the bells are arranged in parallel, the magnet coils are wound with fine copper wires having a comparatively high electrical resistance. In order to secure the maximum efficiency in working a definite ratio must be observed in adjusting the resistance of the line circuit and the total resistance of the bells, signal alarms, or bell relays, etc., connected to the

TABLE I.—RESISTANCE OF MINING BELLS, SIGNAL ALARMS, BELL RELAYS, ETC.

Particulars of Apparatus.	Resistance in Ohms.	Current in Amperes.
Electric bells. Size of gong, 6 inch	8—10	0·20
,, ,, 8 ,,	20—25	0·65
,, ,, 10 ,,	30—35	0·92
,, ,, 12 ,,	40—50	1·30
Electric hooters	—	0·60
Electric bell relays. Short distance	10—50	0·05
,, ,, Long distance	125—200	0·008

circuit. The total resistance of the instruments connected in circuit should in all cases exceed that of the line wire circuit the usual practice being to allow one-third more. For example, a line wire circuit having a resistance of 40 ohms would have bells, relays or other instruments connected having a total resistance of 60 ohms, making for the complete circuit a resistance of 100 ohms, measured at the battery terminals. The distance over which a signal may be transmitted *direct* is limited by considerations of economy in regard to

the size of the battery required to transmit the signals. For distances exceeding two miles it is the usual practice to work the system through the intermediary of relays. The resistance of the signal bells can then be adjusted to suit the size of the local battery. Table I. on p. 43 gives the standard resistances, etc., in which bells, signal alarms, and relays, are usually made for use in mine signal work.

CHAPTER IV

ELECTRIC MINING INDICATORS OR ANNUNCIATORS

When signals are to be received at some central point from a number of different places, it becomes necessary to employ some means of identifying the point of origin of each particular signal. This is sometimes effected by arranging a code of signals in connection with a system of bells, a definite number of rings being allotted to each sending station. The efficiency of this system, which has the merit of extreme simplicity, is, however, discounted by reason of the fact that it is possible for signals to be transmitted at the same instant from two or more sending stations, without the senders being aware that each are using the line, thus leading to a confusion of signals at the receiving station. If the signalling system comprises only a small number of transmitting stations, use is sometimes made of a single-stroke bell and a trembling bell for this purpose, the difference in the ring being easily distinguishable. The difference in tone produced by bell gongs of various shapes and sizes is also frequently utilised for this purpose, but such a method is only applicable to a limited extent and is not to be relied upon with absolute confidence. In most cases some means of indicating, indisputably, the origin of a signal is indispensable. This is best effected by connecting an *indicator* or *annunciator* in circuit with the

signal bells. An electrical indicator or annunciator consists of a mechanism which causes a shutter to drop or an incandescent lamp to glow, or which deflects a needle whenever a signal is being sent.

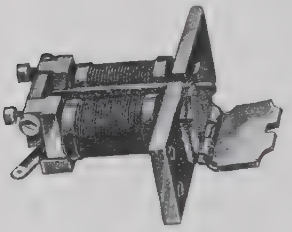


FIG. 31.

Shutter Indicators or Annunciators. — Fig. 31 shows a simple shutter form of indicator mechanism or movement. Its construction

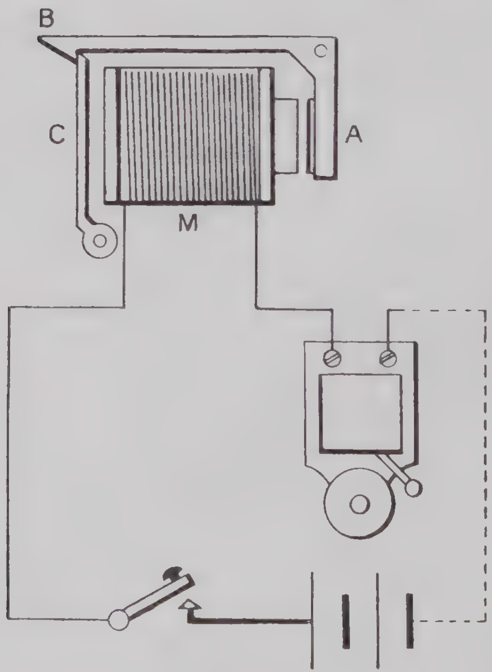


FIG. 32.

and action will be better understood by reference to Fig. 32, which also shows, diagrammatically, the

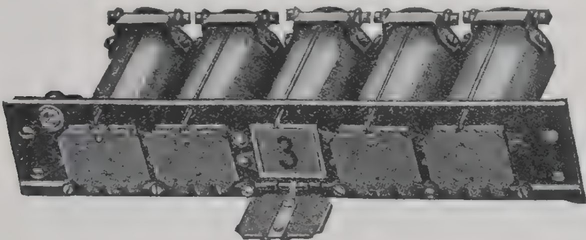


FIG. 33.

method of arranging it in circuit with the signal bell and battery, etc. When current passes through the coils of the electro-magnet, M, it attracts the armature, A, thus raising the catch, B, and so releasing the shutter, C, which drops and displays the number of the circuit to which the movement is connected. Any number of these movements may be utilised corresponding to the different circuits, each one being connected to a separate circuit, together with one or more signal bells which call attention to the position of the

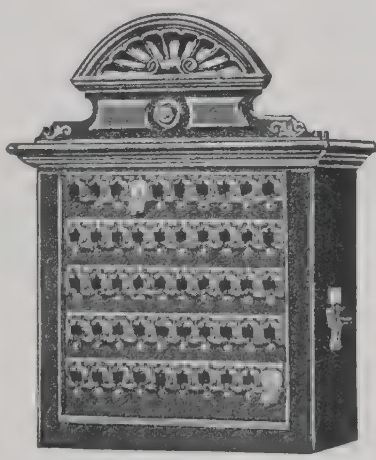


FIG. 34.

shutters. The dropped shutter in this type of indicator movement is usually replaced by hand when the signal has been attended to. Fig. 33 shows a number of these indicator movements fixed on to a strip of metal ready for fixing into a wood or metal case, and Fig. 34 shows a complete indicator.

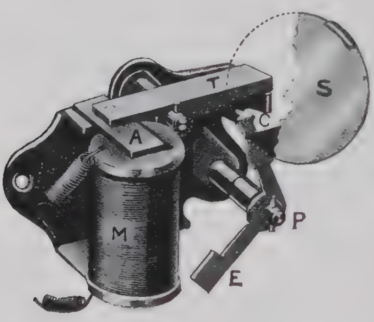


FIG. 35.

Mechanical Replacement Indicator.—Another form of mechanical replacement indicator or annunciator movement suitable for mining work is shown in Fig. 35.

FIG. 36.

This has the advantage that it occupies less space than the preceding type thus rendering the complete indicator more compact. Although its construction differs

somewhat from that described above (Fig. 32), its action is very similar. It consists of an electro-magnet, M, provided with an iron armature, A, and a trigger, T. The drop shutter, S, is pivoted at P, and is provided with a catch, C, which engages with the trigger, T. The extension, E, on the shutter, S, is provided for the purpose of replacing the shutter, which is effected by means of a sliding rod, not shown in the illustration. When in the normal condition and ready to receive a signal the shutter is retained in the upright position, as shown (Fig. 35) by the trigger. When a current

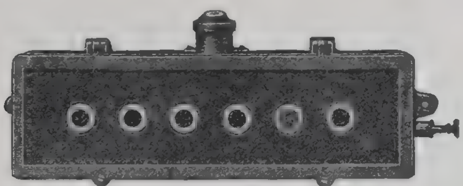


FIG. 37.

passes through the coils of the electro-magnet, M, the armature is attracted and the trigger releases the shutter which drops down. In dry places, such as engine houses, etc., these movements may be fitted into a polished hardwood case fitted with plate-glass front and metal screen, as illustrated in Fig. 36. The shutters are replaced by means of a sliding rod which projects through the side of the indicator case. When intended for use in wet and gaseous places the movements are enclosed in a strong galvanised cast-iron case, as shown in Fig. 37. The front of the case is also of cast-iron and is fitted with glazed apertures for displaying the numbers of the circuits. The front is secured to

the case by means of screws and the joint made watertight and gastight by an india-rubber washer or gasket. The mechanical replacement rod works through a vaseline chamber. A cable inlet or gland is provided for leading in the cable. The diagram (Fig. 38) shows the arrangement of the internal electrical connections of a mechanical replacement indicator and also that of the bell circuit.

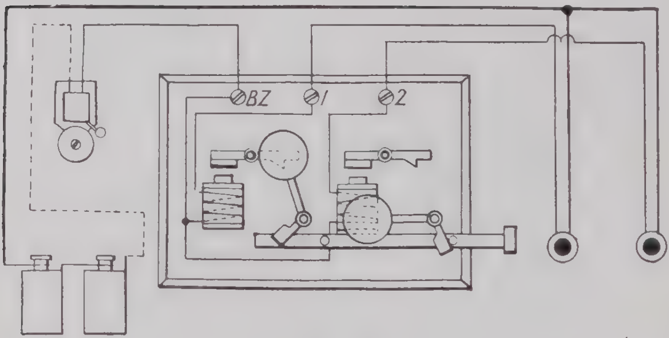


FIG. 38.

Electrical Replacement Indicator.—The shutters of an indicator may be replaced electrically and from a distance, and this in many cases offers an advantage over mechanical replacement. The movements of this type of indicator are of two kinds, viz., polarised and non-polarised. In the former a small permanent magnet forms part of the mechanism from which circumstance arises the term *polarised* as applied to this kind of indicator movement. A form of polarised electrical replacement indicator movement is illustrated in Fig. 39. The movement consists of two

spools of insulated copper wire, S^1, S^2, mounted on two soft iron magnet cores which are fixed to a metal backplate, P. A small horse-shoe permanent magnet, M, swings freely between the two magnetising coils, being pivoted in a bracket, B, fixed to the metal backplate. An indicating flag, F, is fixed to the permanent magnet and projects above its centre of gravity so that a slight impulse will cause the flag to overbalance and remain at rest in either position to the right or left of a line passing through the centre of the movement. The windings of each of the magnetising coils are totally distinct from each other, the two ends of one coil being connected to the operating or signal circuit, while the windings of the other coil are connected to a replacement circuit which includes also a push and battery. The action of the electrical replacement movement is as follows: When current flows through the magnet coil connected to the signal circuit the poles of the permanent magnet are attracted, causing the flag to overbalance and drop, thus indicating that a signal has been sent from the distant station. The flag is replaced in its normal position, out of sight, by pressing an ordinary bell push connected to a battery circuit, which has the effect of causing the opposite coil to become

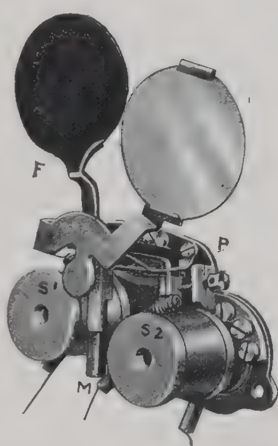


Fig. 39.

magnetised, thus attracting the poles of the permanent magnet in the opposite direction. While this type of indicator movement possesses a high efficiency, and is extremely sensitive, it has the objection that in the course of time the permanent magnet is liable to lose its magnetism, this causing the movement eventually to become sluggish in action. In cases where extreme sensitiveness is not required a non-polarised type of movement is preferable. A good pattern of this kind of indicator movement is shown in Fig. 40. The mechanism consists of two iron magnet cores with yokes which are fixed on to a base-plate or frame of brass or other non-magnetic material. These two cores together with their yokes form two entirely separate electro-magnets, being energised by two magnetising coils or spools the circuits of which are entirely separate and distinct. The shutter is riveted to a soft iron armature which is pivoted in front of the two electro-magnets which are arranged one above the other, vertically. The lower electro-magnet is connected to the working or signalling circuit, and when current flows through its magnetising coils, the armature is attracted causing the shutter to drop. The upper electro-magnet serves the sole purpose of replacing the shutter, being energised by current derived either from the main battery or a separate local battery reserved solely for replacement purposes may be used.

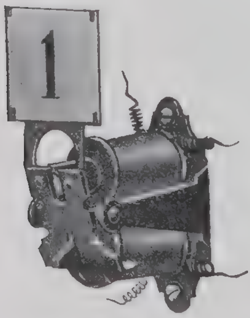


FIG. 40.

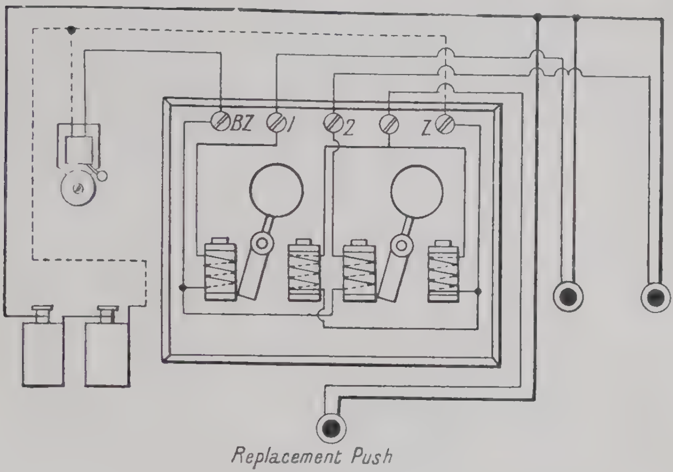


FIG. 41.

The replacement battery is brought into action by means of a common bell push which may be fixed at any convenient distance from the indicator. The manner in which the various connections of an electrical replacement indicator are arranged both in regard to the working and to the replacement circuits is shown in the diagram (Fig. 41).

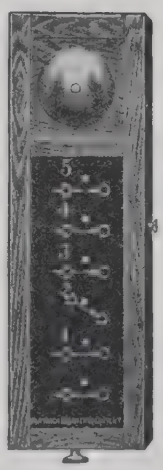


FIG. 42.

Needle Annunciators.—A type of annunciator which has had an extensive application in America is the *needle annunciator* (Fig. 42). In this indicator the receipt of a signal is indicated by a needle which, under normal conditions, remains either in a horizontal or in

a vertical position, being deflected from this position by the passage of the signalling current, so that it takes up a position at an angle of about 45 degrees from the horizontal. The needle remains locked in this position until the signal has been attended to and the needle reset to its former position. The construction and action of the mechanism of the needle annunciator is illustrated in Figs. 43 and 44. The soft iron core of the electro-magnet, C, has a hole drilled through it, in which turns the shaft, S. An arrow-shaped needle is attached at the front end of the shaft or spindle, over the face of the annunciator. A notched arm, B, is fixed on the rear of the spindle and is held in a horizontal position by the end of the soft iron armature, A. When the current flows through the magnetising coils of the electro-magnet, C, the armature, A, turns on its

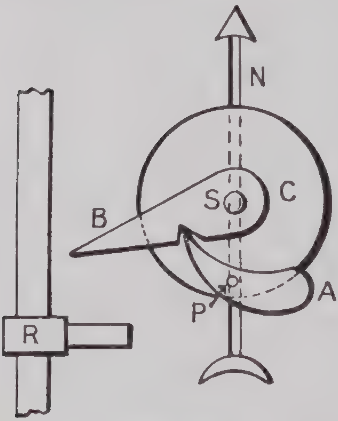


FIG. 43.

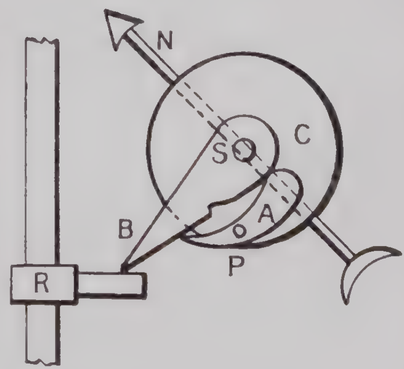


FIG. 44.

pivot, P, towards the core of the magnet, C, as in Fig. 44, unlocking B, which falls and thereby partly rotates the spindle, S, and the indicating needle. In resetting the indicating needle and arm a button projecting from the bottom of the case is pressed upwards and this raises a rod carrying an arm, R. This latter arm in turn raises B to its former position, the heavy end of the armature, A, falls, and its pointed end locks B.

Visual Signal Indicators.—From the nature of the work they are called upon to perform in connection with mine signal installations, indicators are of necessity frequently required to be placed in positions where the light is either very dim or entire darkness prevails. Under these conditions the ordinary type of indicator is of course useless, and recourse must be had to *visual signal indicators*. A number of different patterns of these indicators are available for this purpose. Different coloured lamps are often used to show from what part of the mine the signal comes. Another method is to employ small incandescent lamps fitted into a suitable case and arranged behind a numbered glass screen in place of the electro-magnetic movements as used in ordinary type indicators. A visual signal indicator of this latter kind is illustrated in Fig. 45. As will be

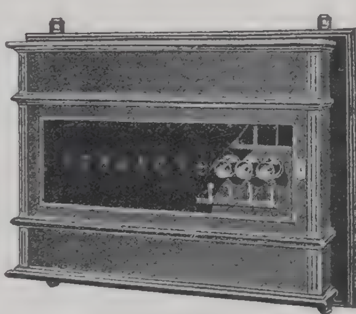


FIG. 45.

seen, a number of small incandescent lamps are fitted behind a numbered glass screen, and in order to ensure that only one number will be illuminated by each lamp, the lamps are placed inside metal tubes which are fitted close up against the glass screen, and provided with small silvered reflectors. A fuse is fitted to each lamp and circuit.

Visual Signal Indicators with Continuous Action Relay and Electrical Replacement.—The contact made in transmitting a signal from a distant station to the indicator is necessarily only momentary and, in consequence, when visual signal indication is employed, the lamps are only illuminated for a very brief period if worked direct from the main line wires, certainly not long enough for the engine man to determine with certainty from which district of the mine the signal originates. For this reason the lamps are generally arranged in circuit with a special form of continuous action relay. This relay is formed by making a simple modification of the circuit connections in the ordinary type of relay (Fig. 27), and consists in inserting a small incandescent signal lamp between the two inner terminals of the relay.

The arrangement of the connections and circuits is shown in the diagram (Fig. 46). The whole system is operated by means of the main battery, MB, consisting of an accumulator battery, or a motor generator or transformer may be used for the service. The working circuit is operated by means of plain circuit closers or ringing keys, K^1, K^2. The signal bell, SB, may be worked either direct off the line circuit but preferably through the medium of a relay, R^3, operated by the main battery or a separate local battery. The relays,

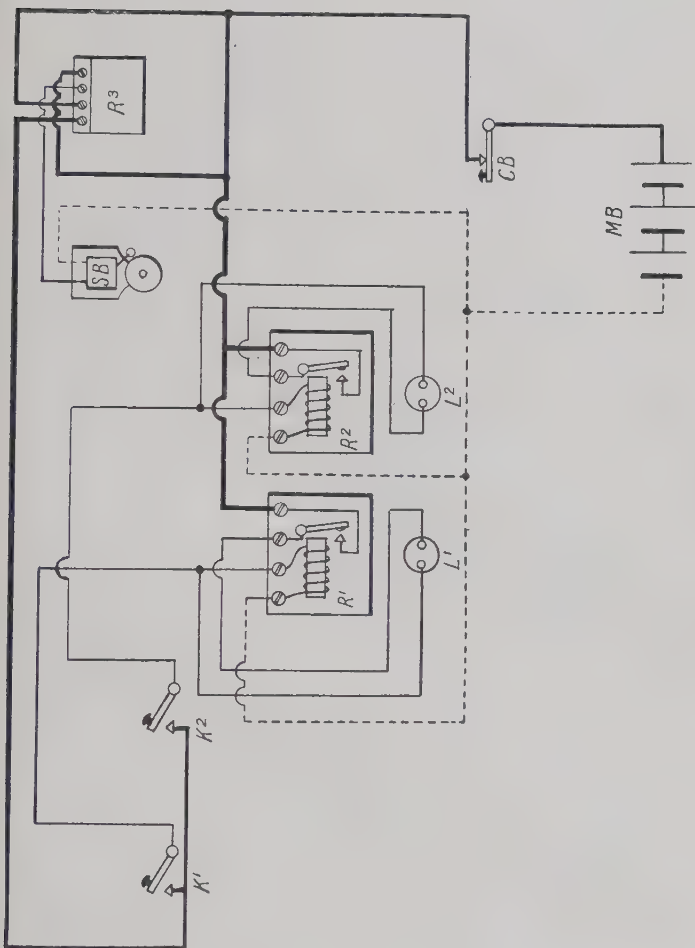


FIG. 46.

R^1, R^2, are arranged for operating the signal lamps, L^1, L^2, and it will be noted that the two terminals of each lamp are connected to the two inner terminals of each relay. The circuit-breaking key, CB, is for the purpose of breaking the circuit of the main battery, MB, and also the lamp circuit. On closing the line circuit, by means of the ringing key, K^1, for example, the current flows from the positive pole of the main battery, MB, and through the bell relay, R^3, operating the signal bell, SB. It then flows by way of the lamp relay, R^1, to the negative pole of the battery. In flowing through the coils of the lamp relay, R^1, it operates the contacts of a local circuit in which is included the signal lamp, L^1, which immediately lights up. On releasing the ringing key, K^1, the lamp still continues to remain illuminated, owing to the current flowing in the local circuit, until the signal is attended to, when it is extinguished by depressing the circuit-breaking key, CB, which may be fixed in any convenient position and at any distance from the indicator. The signal bell, SB, may be rung any number of times without interfering in any way with the action of the signal lamp and relay. The lamps used in connection with visual signalling indicators are of the metal filament type, and suitable for any voltage ranging from 4 volts to 25 volts, and varying from $2\frac{1}{2}$ candle power to 8 candle power according to the position in which the indicator is placed. The adoption of visual signalling indicators involves the use of an electrical generator of some considerable capacity and capable of supplying current of sufficient strength to operate the system. Ordinary Leclanche cells of even the largest size are of no practical use for the purpose and

soon become polarised and exhausted. The most convenient source of power is an accumulator battery of a capacity of about 40 ampere hours. A battery of this size will only require recharging at intervals of about two weeks under ordinary conditions of working.

Bell Signal Indicators.—These instruments, of which Siemens' indicator (Fig. 47) is a good example, are now in much demand, and are used in conjunction with bell signalling apparatus to indicate the number of bell strokes given, and also the nature of the signal. They are particularly applicable for shaft winding or haulage in mines. The indicator consists of a dial instrument, and comprises an electromagnet which operates an armature, actuating a pointer through one section of the dial for each ring of the bell, so that the number of rings received is recorded by the pointer. It is provided with a releasing mechanism by means of which the pointer can be set back to zero. This last operation can be effected either by hand at the instrument by means of a lever provided, or electrically from a distance by a press-button switch in the engine house. This switch may also be so arranged that it is automatically operated by the engine. The indicator can be applied to any existing bell signalling apparatus

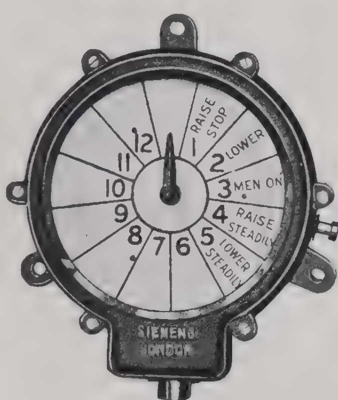


FIG. 47.

without any alteration to the latter, it being connected in series with the signal bell.

The following description illustrates the application of the bell signal indicator for shafts with one level only. The method in which the various appliances are

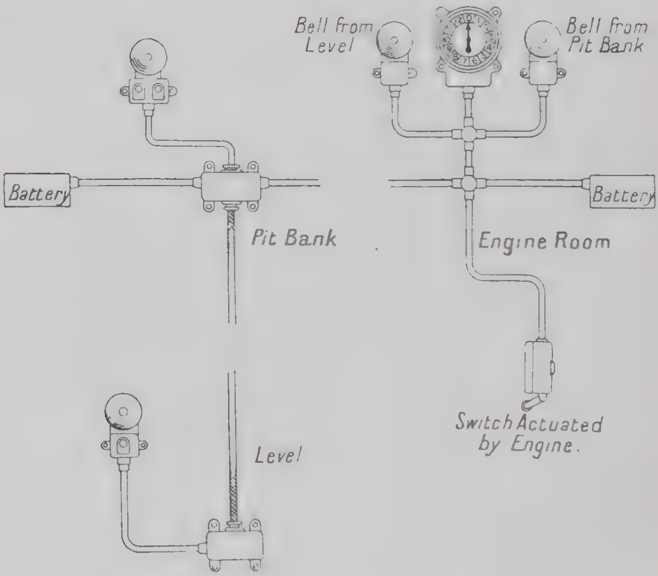


FIG. 48.

arranged in relation to each other is shown in the diagram (Fig. 48). Two bells with a dial indicator are provided in the engine house, the latter indicating the number of strokes on the bells, thus forming a visual indication of the order received. A bell and two press switches are also provided at the bank, and a bell and press switch at the level of the mine which enable the usual order of bell signals to be used.

The following description of working the signals is only taken as an example to illustrate how the apparatus may be used. The procedure may be varied to suit the requirements in each particular case. For instance, if men are to descend the shaft, the banksman gives three rings on his own bell and that at the level by pressing one of the switches at the bank. To this signal the onsetter at the level replies, before men enter the cage, by giving the bell at the bank three rings, at the same time one of the bells in the engine house will ring three times, and the indicator moves forward one step for each ring and will stand at 3. When the onsetter's cage is ready to ascend he signals the banksman and engineman one ring, the pointer on the indicator moving forward to 4. To start the descending cage the banksman now signals to the engineman by pressing the second switch and ringing the second bell in the engine room once. The indicator pointer moving to 5, the engineman knows that the cage is ready to descend and proceeds accordingly, at the same time putting the pointer back to zero by means of the press switch. This last operation can also be effected by a release switch actuated by the engine, so that it is impossible for the engine to be moved and the old order to remain on the dial. The divisions on the dial allow various extra orders to be used up to twelve bell strokes. A point to note in connection with the above system is that whenever a signal is sent from the level or bank of the mine, the bell at either of these places rings, thus confirming that the signal has been received correctly. A diagram of bell signal indicator wiring and connections is given in Fig. 49.

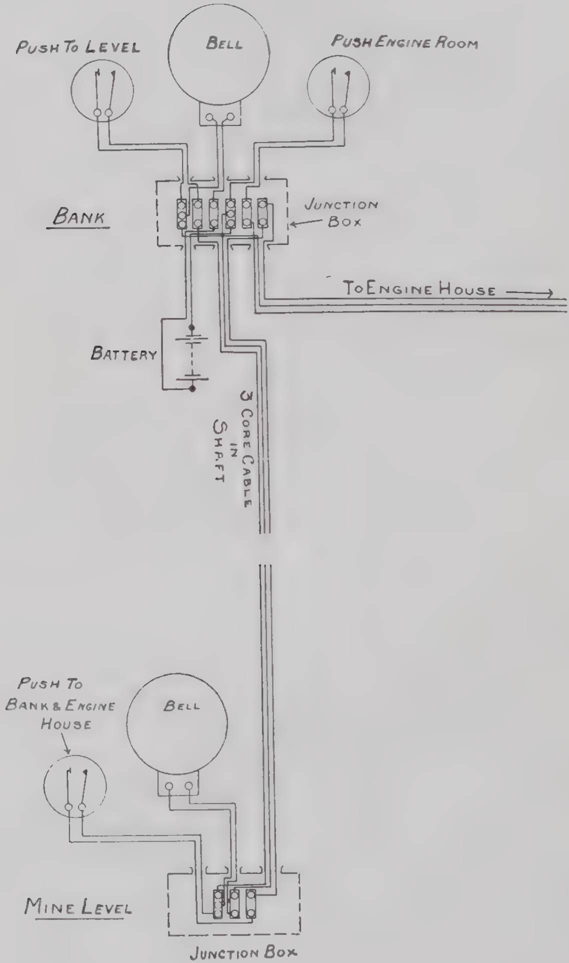

PUSH TO LEVEL
BELL
PUSH ENGINE ROOM
BANK
JUNCTION BOX
TO ENGINE HOUSE
BATTERY
3 CORE CABLE IN SHAFT
PUSH TO BANK & ENGINE HOUSE
BELL
MINE LEVEL
JUNCTION BOX

FIG. 49.

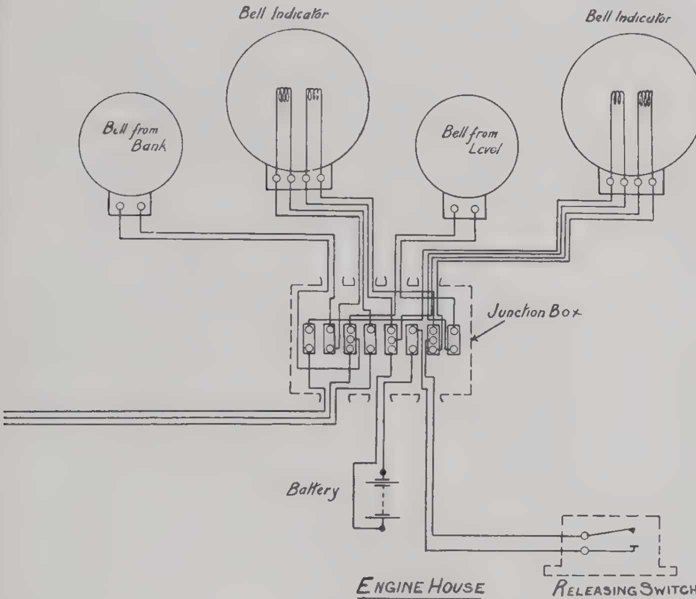


Fig. 49.

The bell signal system with indicator can also be adapted for mines having two or more levels, in which case it is used in conjunction with level indicators as illustrated in Fig. 50. These level indicators are controlled by the banksman who indicates to the onsetters to which level the cage is going, and to the engineman to which level to work the cage. Means are provided in this apparatus whereby only the level to which the cage is working can send orders to the engineman. It is therefore impossible for the onsetter of another level to send a signal to the engine house and cause the indicator to register a wrong number of bell

strokes. Each onsetter, however, can communicate to the banksman to indicate when he requires the cage

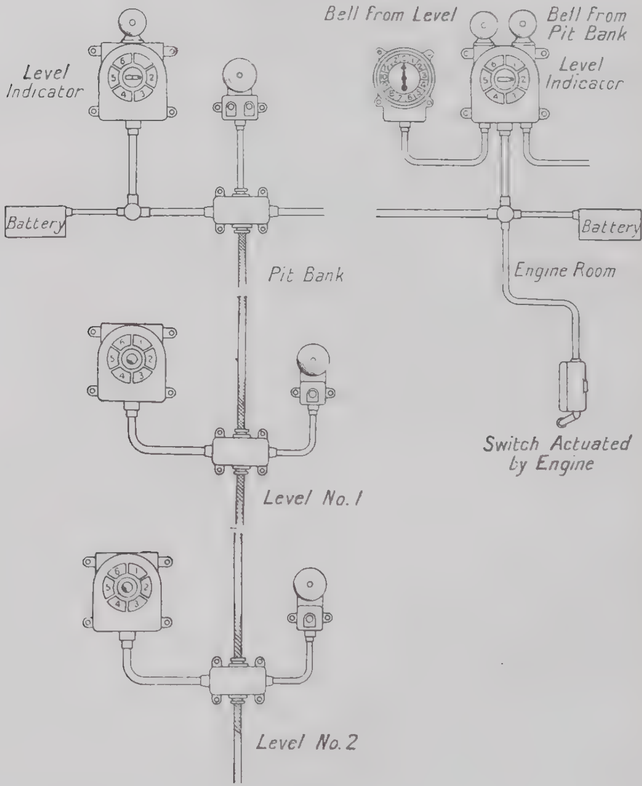


FIG. 50.

to stop at his level. In place of level indicators a separate bell signal indicator may be used for each level.

CHAPTER V

ELECTRIC GENERATORS FOR MINE SIGNAL INSTALLATIONS

Now that most mines are equipped with electric lighting or power installations it is often convenient to derive a supply of electrical energy required, either in whole or in part, for the operation of signalling systems from this source. This is particularly the case if visual signalling, now so much in evidence, is adopted, as this system requires some more powerful source of current than that obtainable from the ordinary Leclanche cell as used for bell signalling. Nevertheless, as absolute dependence cannot always be placed on the continuous operation of the prime movers, electric generators, and other moving machinery constituting the source of supply, it is also desirable in most cases to have some independent source of power held in reserve in case of failure of the main supply. This can be most conveniently furnished by an accumulator or primary battery. In order to render the risk of failure in the transmission of signals as small as possible, in large installations of signals both sources of supply are frequently employed in combination, primary batteries or accumulators being used for operating the bell signals and the other for the visual signals. When electric lighting or power circuits are absent the only

practicable source of power is, of course, the primary battery.

Transformation of Electrical Pressure. — The maximum voltage permissible for operating mine signalling circuits in Great Britain is 25 volts, and quite apart from any question of compulsion, this forms a very convenient voltage for this purpose. The lowest practicable voltage for use in electric lighting in connection with mining installations is 100 volts, and in the case of power circuits the voltage is usually higher than this limit. When, therefore, a supply of power is to be taken from lighting or power mains for electric signalling purposes, it becomes necessary to reduce the pressure to that required for ringing the bells. The most convenient method of reducing the pressure in direct current installations is by means of a motor generator; in alternating current supply, a transformer forms the most suitable device for this purpose. In cases where a direct supply from the mains is not favoured and an accumulator is preferred for working the signals, it may be charged from direct current lighting mains, either a bank of incandescent lamps or a special resistance being used to reduce the pressure to that required for charging the battery. This method forms at once the simplest and is at the same time the most wasteful in current consumption, but in cases where power is cheap this question of cost need not be taken seriously into consideration. Accumulators may also be charged from alternating current mains through the medium of a vibratory rectifier, and this offers a very convenient means for the purpose, the apparatus being economical in prime cost and also in operation and maintenance.

Direct-current Motor Generator Installations.—When a signalling system is to be operated from direct current mains a motor generator is necessary for reducing the pressure of the electric supply to that required by the bells, viz., a maximum of 25 volts. The signalling circuits must be entirely separate from the main supply, and this is important to avoid any risk of shock. For this reason a machine fitted with a single armature and

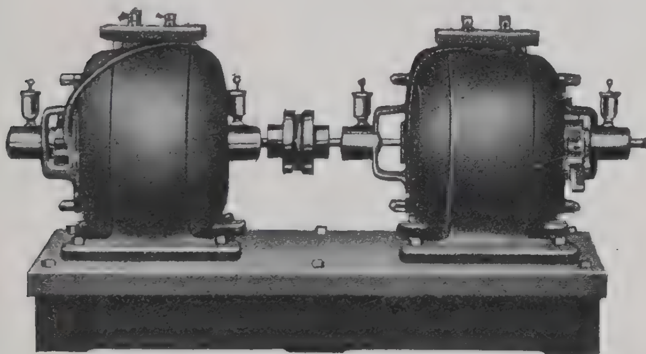


FIG. 51.

two commutators is not permissible. The machine should consist of a small shunt motor, wound for the voltage of the supply circuit and coupled to a dynamo of corresponding size and wound to give the voltage required for the bells. This may be anything from 6 volts upwards, but not exceeding 25 volts. If the voltage of the supply fluctuates to any extent this will need to be taken into account and due allowance made in fixing the maximum voltage given off by the dynamo. Assuming that the motor generator is connected to a

lighting circuit the variations in the voltage will not exceed more than 5 per cent. to 10 per cent. Accepting the latter figure as the maximum the normal voltage required at the terminals of the dynamo will be 22 volts. The motor generator should be of the type shown in Fig. 51, consisting of motor and dynamo coupled together and bolted on to a common bed-plate. The two shafts being coupled together enables the machine to be run at a fairly high speed, from 1,500 to 2,000 revolutions per minute, according to the size of the

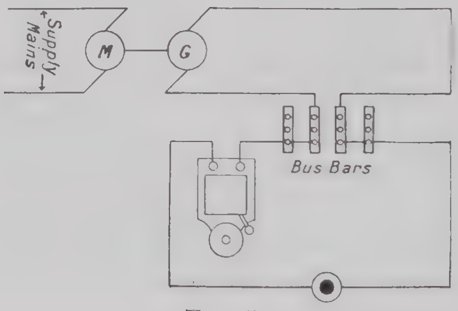


FIG. 52.

machine. In regard to the power required to ring the bells, which determines the size and output of the machine, it may be taken that one ampere per bell will be required to furnish a reliable signal and compensate for leakage, etc. of the line wires and other parts of the system. The motor of the generator should be provided with a double pole main switch and pair of enclosed fuses, of suitable capacity to carry not more than 50 per cent. of the maximum capacity of the machine. If a larger motor than one half horse-power is required, a starting switch and resistance will also be

necessary. No switch is needed on the low tension side of the generator, unless the machine is also supplying current for some other purpose. The two mains should be carried direct to the bus bars of a small double pole distribution board of the kind as used for electric lighting circuits. This may be provided with a suitable number of small detachable fuses of 3 to 5 amperes capacity to isolate the different circuits, and prevent a fault on one section stopping the whole of the signalling. The fuses should be mounted on porcelain bases and enclosed in a cast-iron gas and watertight case. A further and almost indispensable addition to the signalling system is the provision of a small lamp fixed in a prominent position and connected through a fuse to the bus bars of the distribution board. This acts the part of a pilot lamp and forms a continuous indication that the signalling supply is in good order. Fig. 52 is a diagram showing the arrangement of the motor generator and its connection to the power supply and low voltage circuits, etc.

Motor Generator and Accumulator.—In order to obviate any danger of the complete failure of the electrical supply required for operating a signalling system, occurring when obtained from a motor generator, an accumulator can be arranged to work in parallel with the dynamo of the machine. This combination has the advantage that if the motor generator ceases to work, either through a fuse blowing or other cause, the accumulator immediately takes up the load and continues to supply current to the low voltage signalling circuit without interruption of the service. The arrangement of the accumulator with its connections in parallel with the motor generator and with the

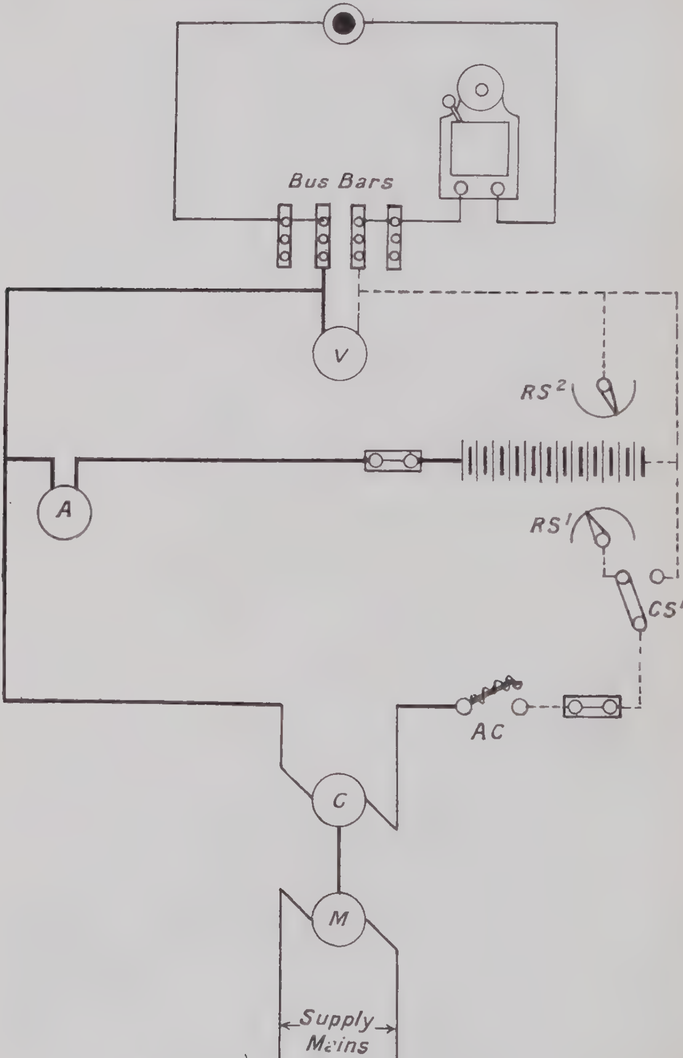


Fig. 53.

signalling circuits is shown in the diagram (Fig. 53). MG is the motor generator provided with double pole main switch and fuses on the high tension side of the supply. AC is an automatic electro-magnetic battery charging switch which connects the generator to the accumulator and low tension supply circuit as soon as the voltage of the generator attains the desired limit. CS^1 is a two-way switch for placing the generator either direct on to the signalling circuit or in parallel with

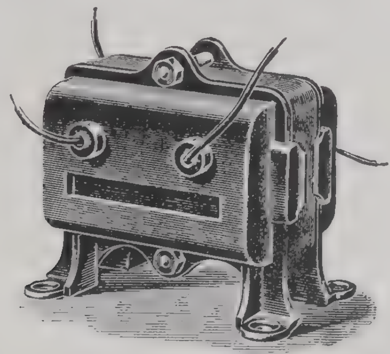


FIG. 54.

the accumulator. The voltage of the accumulator is controlled and adjusted by means of the regulating switches, RS^1, RS^2. An ammeter, A, and voltmeter, V, are provided for measuring the output of the plant. The different signalling circuits are connected to a distributing board.

Alternating Current Transformer Supply.—In cases where an alternating current is installed, a supply of current transformed to the correct voltage required for signalling purposes may be obtained direct from a

transformer connected to the lighting or power mains. This has the great advantage of having no moving parts, and consequently when once fixed in position it can be left for long periods without attention. It is most important, however, that a true transformer be used and not an *auto-transformer*. The difference between the two appliances from a cursory external inspection is not very apparent, and it is only when the arrange-

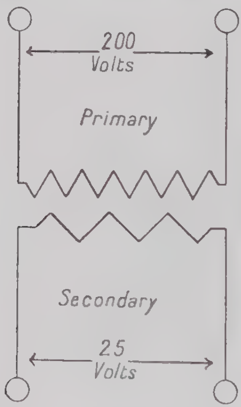


FIG. 55.

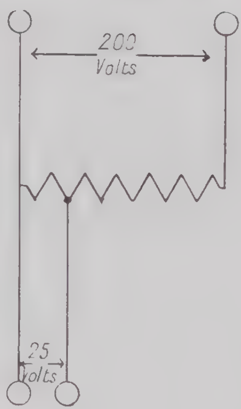


FIG. 56.

ment of their windings and internal circuits come to be examined that the points of difference in their construction are revealed. Fig. 54 shows a type of transformer specially adapted for bell ringing and signalling purposes, and Fig. 55 illustrates the arrangement of its circuits as compared with those of an auto-transformer (Fig. 56). It will be seen that a transformer has two entirely separate and distinct windings while the auto-transformer has only one, a tapping being taken from the main winding carrying the full pressure of the

supply at some point where the required difference of potential exists. When using an auto-transformer it would thus be quite possible for a person to receive a shock at the full pressure of the supply, whatever that might be, when using the signalling apparatus if the insulation were defective at any point, so that one or

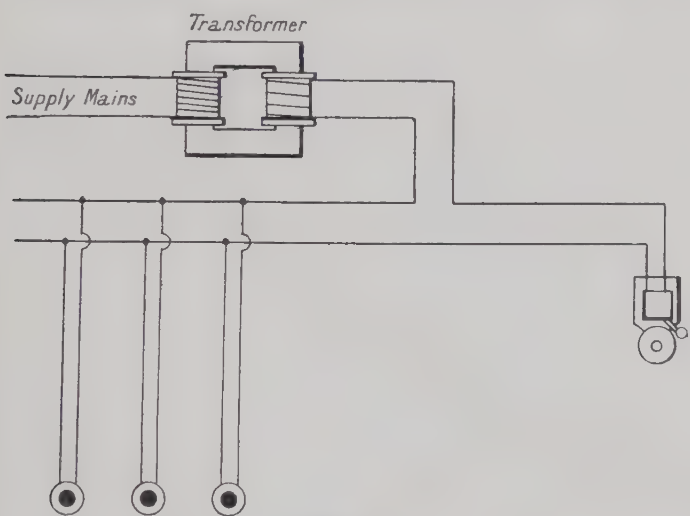


FIG. 57.

other of the supply mains became earthed. The arrangement of the transformer in its relation to the supply and bell signalling circuits is shown in Fig. 57. As regards the operation of bells from the transformer, in connecting up the mining bells to be rung it will be found advisable, if these are of the trembling pattern, to cut out of circuit the contact makers and to connect the two magnet coils of each bell in parallel instead of

in series as usually carried out. Adjustment of the spring of the armature and hammer will then be found to give satisfactory ringing.

Vibratory Rectifiers.—A method of obtaining a supply of electrical energy, suitable for signalling purposes, from an alternating current system is by the aid of a *vibratory rectifier*. This rectifier is a converter which, in the smaller types, transforms single-phase alternating current of 100—250 volts into rectified current of 7·5 to 25 volts; in the larger types higher voltages and currents are provided for. Although it is possible to work signal bells and other alarm devices direct from its terminals, this method does not offer any conspicuous advantages over the ordinary transformer system, and it is only when used in connection with the charging of accumulators from an alternating current supply, that its merits become manifest.

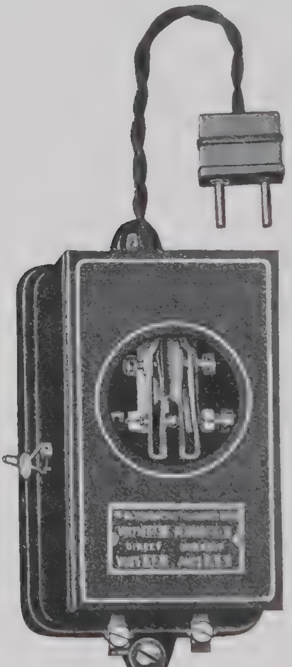


Fig. 58.

"Adnil" Rectifier.—The "Adnil" rectifier (Fig. 58) consists essentially of a transformer with vibrating contact in the low tension secondary circuit. A stray field in the transformer operates the armature and

contact system of the rectifier at the two points of the alternating current curve, producing a rectified current. By this system of operating the vibratory contacts by the transformer field perfectly synchronous working can be adjusted by mechanical means such as small

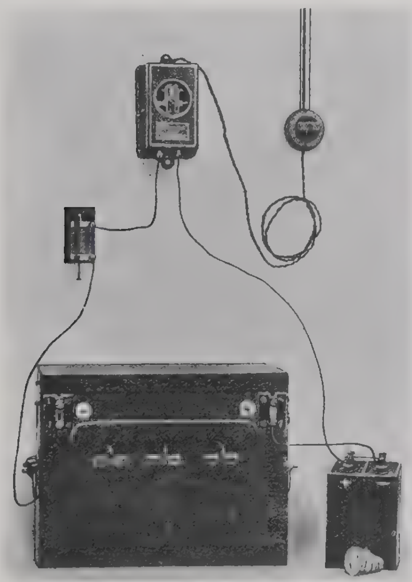


FIG. 59.

brakes, springs, etc., without the use of auxiliary apparatus. The efficiency on load and on open circuit corresponds to that of transformers of similar output. The direct current generated is suitable for charging accumulators. Fig. 59 shows the method of arranging the various accessories required with the system, and

the connections of the apparatus to the alternating current mains and to the accumulators to be charged. All heavy losses in the compensating resistances, transforming plant or carbon filament lamps otherwise necessary are avoided, a small adjusting resistance only being used as shown in the illustration. In the event

Fig. 60.

of the voltage failing in the alternating current line, due to interruption or short-circuiting, the accumulator cannot discharge through the rectifier as it is automatically switched off. The rectifier when properly used and adjusted, and under normal conditions of the alternating current supply, works without sparking. Should, however, sparking arise it can at once be stopped by use of the adjusting screw provided for the

purpose. The adjustment of the rectifier for different frequencies can be carried out in the simplest manner by means of regulating screws. Fig. 60 shows the rectifier and all necessary accessories required for working the system mounted on a marble slab for convenience of operation.

CHAPTER VI

PRIMARY BATTERIES FOR SIGNAL INSTALLATIONS

In the large majority of cases a battery of some kind is essential in connection with mine signal installations, even though a supply of current is being taken from lighting or power mains, as absolute reliance cannot always be placed on this latter source of supply, and a battery held in reserve is most desirable. The battery may be made up of primary cells or an accumulator may be used, in accordance with the nature of the work the battery is required to perform. Primary batteries are of no practical use for visual signalling with lamp indicators, for which purpose an accumulator battery is best adapted. A convenient size of accumulator battery suitable for this purpose in connection with an ordinary mining installation of either winding or haulage signals, is one of about 40 ampere hour capacity and of any desired voltage up to 25 volts.

Types of Primary Batteries for Signalling Installations.—The primary cells which, as the result of long experience, have been found to give the best results in mining work are the Leclanche and Fuller (or Bichromate), the former cell being adapted for working under ordinary conditions and the latter in cases where the work is exceptionally heavy. These two types of primary cells have now stood the test of many years,

and are regarded as the standard cells for mining work, but it may be mentioned that under certain conditions the Edison-Lalande cell also gives good results, especially where a large current is required. Its comparatively low E.M.F. (·75 volt) is, however, a disadvantage. Dry cells are also occasionally used for special purposes in connection with mining installations, but as a rule they are more expensive in prime cost and in maintenance than the ordinary wet cells.

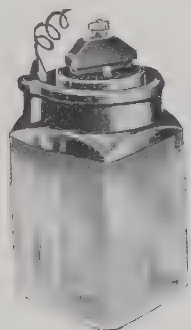


FIG. 61.

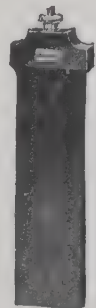


FIG. 62.

The Leclanche Porous-Pot Cell.—This well-known cell, shown in Fig. 61, consists of a square glass jar, ending at the top in an almost circular collar, and containing a cylindrical porous pot in which is placed a plate of carbon, surrounded by a depolarising mixture of granulated peroxide of manganese and carbon, the whole forming the negative element of the cell. The top of the porous pot is sealed with bitumen, two small air holes, usually fitted with glass tubes, being left therein to provide for the escape of any gases which may be generated inside the porous pot. A brass

binding screw is fixed to the top of the carbon plate sometimes in a lead cap cast around the top of the plate, but preferably by forming the carbon plate with a solid carbon head into which the terminal is secured, as shown in Fig. 62. When a lead cap is used great difficulty is experienced in preventing the exciting fluid of the cell from attacking the lead, converting it into chloride and rendering the battery useless. When fitted to the carbon plate in the manner shown in Fig. 62, the end of the terminal is completely encased and protected by the carbon and if ordinary precautions are taken when charging the battery, to avoid spilling the electrolyte there is not much fear of corrosion taking place. An amalgamated zinc rod having attached to it an insulated connecting wire forms the positive element and is placed in the glass jar beside the porous pot. The outer glass jar is filled with a solution of sal-ammoniac (ammonium chloride) up to a level about 2 inches from the top of the jar. The porous pot referred to, complete with carbon plate and terminal, is shown in Fig. 63, and zinc rod in Fig. 64. As practically no local action takes place in the Leclanche cell when the circuit is open (provided that the zinc rod is kept well amalgamated) this type of cell shows great durability and economy in working when employed for giving intermittent currents. Its great popularity is further due to its

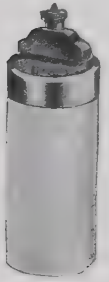


FIG. 63.

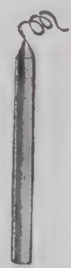


FIG. 64.

simplicity and to the small amount of attention which it requires. These cells are made in three sizes of the dimensions and capacities shown in the following table :—

TABLE II.—SIZES AND PARTICULARS OF POROUS-POT LECLANCHE CELLS.

Size.	E.M.F. in Volts.	Internal Resistance in Ohms.	Weight in lbs. (including charge).	Overall Dimensions, including Terminal, in inches.
No. 1. Three pints	1·6	0·8	$5\frac{1}{4}$	$9\frac{1}{2}$ high $\times 4\frac{5}{8}$ sq.
,, 2. Quart .	1·6	1·0	3	8 ,, $\times 3\frac{5}{8}$,,
,, 3. Pint. .	1·6	1·4	$2\frac{1}{4}$	7 ,, $\times 3$,,

The largest size of cell only is used for mine signal work.

Chemical Charge for Leclanche Cells.—Considerable difference of opinion exists as to the correct proportions of sal-ammoniac and water to be used in charging Leclanche cells. Formerly, it was the usual practice to employ a saturated solution, together with an excess of sal-ammoniac in the form of crystals in the cell. It is now generally agreed that this practice is objectionable, as it tends to favour the deposit of crystals of the double chloride of zinc and ammonium on the zinc rod and on the porous pot. As this salt is insoluble under these conditions, the action of the cell is interfered with to a considerable extent by their presence. Probably the best practice is to graduate the strength of the solution in accordance with the work the battery will be called upon to perform, thus, for exceptionally

heavy discharges, a saturated solution, composed of about 4 ounces of sal-ammoniac to one pint of water, may be employed, and for ordinary working a somewhat weaker solution, consisting of about 2 ounces of sal-ammoniac to a pint of water, will give the best results. In positions where the temperature is high a weaker solution should invariably be used. Working on this basis the following quantities of sal-ammoniac may be used for a single charge for each size of cell :—

TABLE III.—CHEMICAL CHARGE FOR LECLANCHE CELLS.

Size of Cell.	Saturated Solution.	Ordinary Solution.
	Sal-ammoniac.	Sal-ammoniac.
No. 1. Three pint .	14 ounces	6 ounces
,, 2. Quart . .	7 ,,	4 ,,
,, 3. Pint . .	4 ,,	2 ,,

Porous-Pot Leclanche Cell with Cylindrical Zinc.— This cell (Fig. 65) consists of a glass or earthenware

FIG. 65.

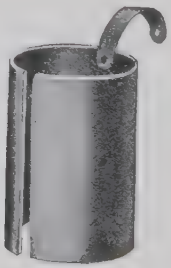


FIG. 66.

jar containing a zinc plate bent into cylindrical shape, as shown in Fig. 66, the porous pot being placed in the centre. The advantage of this arrangement over the ordinary pattern lies in the largely increased surface of zinc exposed to the action of the electrolyte, resulting in a diminished internal resistance of the cell and a greater capacity for useful work. This form of cell is made in one size only, particulars of which are given in the following table :—

TABLE IV.—SIZE AND PARTICULARS OF LECLANCHE CELL WITH CYLINDRICAL ZINC.

E.M.F. in volts.	Internal Resistance in Ohms.	Weight of Cell (without charge).	Outside Dimensions of Complete Cell in inches.
1·6	0·5	6 lbs. 3 ounces	9 high $\times$ $5\frac{1}{4}$ diameter.

Chemical Charge for Leclanche Cell with Cylindrical Zinc.—The quantity of sal-ammoniac required for a single charge for this pattern cell is as follows :—

For a saturated solution . . 14 ounces.
For an ordinary solution . . 6 ,,

Central Zinc or Carporous Leclanche Cell.—In this cell (Fig. 67) the carbon plate is replaced by a perforated cylinder of porous carbon. This is formed with an enlargement or top to which a brass terminal is fixed (Fig. 68). A tube of porous earthenware is fixed into the centre of this carbon pot, and the annular space existing between the inner wall of the carbon pot and the exterior wall of the porous tube is filled with the depolarising mixture of peroxide of manganese and

carbon, similar to the mixture used in the ordinary porous-pot Leclanche cell. A cap or cover of glass closes the open end and forms the base of the pot. The zinc rod is inserted in the porous tube fixed in the centre of the pot. This form of cell possesses some advantages over cells of the ordinary Leclanche porous-pot pattern. The output is greater and the internal resistance is lower, the depolarising action more rapid, and owing to the small surface of the liquid which it

Fig. 67.

Fig. 68.

exposes and to the fact that the enlarged top of the porous cylinder forms a cover to the glass jar, evaporation is reduced. A defect, however, which is of frequent occurrence in this type of cell may be mentioned, in that the zinc rod often becomes firmly fixed inside the porous tube owing to the formation of hard crystals on its surface, necessitating the renewal of the entire element. As the carbon pot of these cells is somewhat expensive as compared with the porous pot and other types, this fact somewhat militates against its adoption. These cells are made in three

sizes, particulars of which are given in the following table :—

TABLE V.—SIZES AND PARTICULARS OF CARPOROUS LECLANCHE CELLS.

Size of Cell.	E.M.F. in volts.	Internal Resistance in Ohms.	Weight in lbs. (without charge).	Overall Dimensions in inches.
No. 1 .	1·55	0·50	6	9 high × $4\frac{3}{4}$ square.
,, 2 .	1·55	0·75	$4\frac{1}{2}$	8 ,, × $4\frac{1}{4}$,,
,, 3 .	1·55	1·00	3	7 ,, × 4 ,,

Chemical Charge for Carporous or Central Zinc Leclanche Cell.—The amount of sal-ammoniac to be used for a single charge for each size of these cells is as follows :—

TABLE VI.—CHEMICAL CHARGE FOR CARPOROUS LECLANCHE CELLS.

Size of Cell.	Saturated Solution.	Ordinary Solution.
No. 1. .	12 ounces	6 ounces
,, 2. .	8 ,,	4 ,,
,, 3. .	$7\frac{1}{2}$,,	$3\frac{1}{2}$,,

Agglomerate Block Leclanche Cell.—In this pattern (Fig. 69), which is a modification of the original porous-pot Leclanche cell, the internal resistance is reduced considerably owing to the absence of the porous pot.

The carbon electrode is placed between two agglomerated blocks of peroxide of manganese and carbon

FIG. 69.

FIG. 70.

formed in a hydraulic press, under great pressure, to the shape shown in Fig. 70. In the usual form of this cell these blocks and the carbon plate are held together

FIG. 71.

FIG. 72.

by two plain india-rubber rings, as shown in Fig. 69. In another form the india-rubber rings are each provided with an eye for holding the zinc rod (Fig. 71). In a third arrangement the zinc rests against a groove

in a porcelain block or gutter, the whole being clasped by the india-rubber bands.

Although this type of cell would appear, superficially, to possess certain advantages over the ordinary porous-pot form, it has been found that under practical working conditions these have not been fully realised. The principal objection to the cell is the fact that the agglomerate blocks have a tendency to disintegrate, small particles of carbon and peroxide being given off, some of which are deposited on the zinc rod. This results in considerable local action taking place, considerably reducing the useful life of the cell. In order to prevent this deposition of carbon particles taking place some makers provide a separate small porous tube in which the zinc rod is placed, as shown in Fig. 72. With this arrangement of the elements the cell, however, is little different from the original porous-pot form, in so far as electrical properties are concerned. Like those of the porous-pot pattern, these agglomerate cells are made in three sizes; the glass jars and zinc rods being of the same dimensions as in the corresponding porous-pot cells.

TABLE VII.—SIZES AND PARTICULARS OF AGGLOMERATE BLOCK LECLANCHE CELLS.

Size of Cell.	E.M.F. in volts.	Internal Resistance in Ohms.	Weight in lbs. (without charge).	Overall Dimensions, including Terminal, in inches.
No. 1 .	1·55	0·5	$4\frac{3}{4}$	9 high × $4\frac{5}{8}$ square.
,, 2 .	1·55	0·6	$2\frac{3}{4}$	8 ,, × $3\frac{5}{8}$,,
,, 3 .	1·55	0·7	2	7 ,, × 3 ,,

Chemical Charge for Agglomerate Block Leclanche Cell.—The quantities of sal-ammoniac required for charging each of the different sizes of these cells in a saturated and ordinary solution is the same as those given for the porous-pot form.

Six-Block Agglomerate Leclanche Cell. — This is another form of the agglomerate type Leclanche cell, constructed to give a considerable output, and having a very low internal resistance. The containing vessel is

FIG. 73.

FIG. 74.

FIG. 75.

an earthenware jar, as shown in Fig. 73. The negative element consists of a fluted carbon rod provided with a brass terminal fixed to one end of the rod (Fig. 74). The rod has six longitudinal flutings or grooves, semicircular in section, in which are fitted six agglomerate blocks of compressed peroxide of manganese and carbon. These blocks are cylindrical in form, each being about 1 inch in diameter and 6 inches long. They are secured to the centre carbon rod by a wrapping of coarse canvas which is held in place by india-rubber

bands (Fig. 75). An amalgamated zinc cylinder (similar to Fig. 66) forms the positive element and this is provided with a copper strap riveted and soldered to the cylinder, for making connection. Owing to its low internal resistance and large zinc and carbon electrodes, the six-block agglomerate cell has a very high working capacity and is, therefore, extensively employed for the purpose of working large installations of bells and signals. These cells further have the advantage of being easily taken to pieces, cleansed, supplied with new parts, and re-charged with electrolyte. The cell is usually made in one size only, viz., three pints capacity, the E.M.F. being 1·55 volts and the internal resistance 0·2 ohms.

Chemical Charge for Six-Block Agglomerate Leclanche Cell.—The quantity of sal-ammoniac required for a single charge of this cell and of three pints capacity is as follows :—

For a saturated solution . . $11\frac{1}{2}$ ounces.
For an ordinary solution . . 6 ,,

Sack Leclanche Cell.—In this cell (Fig. 76) the negative element consists of a tightly compressed mixture of peroxide of manganese and carbon moulded around a central carbon rod and held in place by a wrapping of canvas wound around with cord or string, forming a *sack*, from which the name of the cell is derived. The open end or mouth of the sack may either be closed up by means of a porcelain cap, as shown in Fig. 77, or filled in with bitumen. The positive element consists of an amalgamated zinc plate which may be of plain cylindrical form, as shown in Fig. 66, but is preferably of the shape shown in Fig. 76. In this latter pattern the zinc is cut so that only that

portion remains which experience has indicated to be the most actively consumed during the working of the cell. The zinc cylinder is provided with a hook by means of which it is suspended from the rim of the jar, the zinc being of such depth that it occupies about the middle portion of the jar only. As the zinc in the upper and lower parts of a Leclanche cell is not usually acted upon to the same degree as the central part, this

FIG. 76.

FIG. 77.

FIG. 78.

method of suspension causes less waste, both to zinc and solution, and the whole of the zinc is consumed uniformly. Another form of the sack cell is shown in Fig. 78. In this pattern the zinc, of plain cylindrical shape, rests upon a shoulder or projection formed in the glass containing jar, in such a manner that the zinc is raised to the required position in the middle of the jar. The method of constructing and arranging the elements of the sack cell enables a very low internal resistance to be attained as the resistance of the canvas

sack is very much less than that of an earthenware porous pot. This, together with the fact that it possesses a high capacity and great depolarising power, renders the cell suitable for all work where comparatively heavy currents are taken for fairly long periods, such as in the direct working of large size bells and in general where the porous-pot or agglomerate Leclanche cell is not capable of sustaining the duty required. The sack Leclanche cell is manufactured by different makers in a large variety of sizes ; the following table gives particulars of the sizes most suitable for mine signal installations :—

TABLE VIII. — SIZES AND PARTICULARS OF SACK LECLANCHE CELLS, ADAPTED FOR MINE SIGNAL INSTALLATIONS.

Size of Cell.	E.M.F. in volts.	Internal Resistance in Ohms.	Weight in lbs. (without charge).	Overall Dimensions, including Terminals.
No. 0	1·55	0·10	$10\frac{3}{4}$	9 high × $5\frac{1}{4}$ diameter.
,, 1	1·55	0·14	$5\frac{1}{2}$	$7\frac{1}{2}$,, × $4\frac{1}{2}$,,
,, 2	1·55	0·16	$3\frac{3}{4}$	$7\frac{1}{2}$,, × $3\frac{7}{8}$,,
,, 3	1·55	0·18	$2\frac{3}{4}$	7 ,, × $3\frac{1}{2}$,,

Chemical Charge for Sack Leclanche Cells.—The quantities of sal-ammoniac required for a single charge of each size of cell corresponding to those referred to in Table VIII. are given in Table IX., on p. 92.

Fuller or Bichromate Cell.—Previous to the introduction of the sack Leclanche cell the Fuller or Bichromate was the only low resistance cell capable of use

TABLE IX.—CHEMICAL CHARGE FOR SACK LECLANCHE CELLS.

Size of Cell.	Saturated Solution.	Ordinary Solution.
No. 0. .	$9\frac{1}{2}$ ounces	5 ounces
,, 1. .	$6\frac{1}{2}$,,	$3\frac{1}{2}$,,
,, 2. .	$5\frac{1}{2}$,,	3 ,,
,, 3. .	$4\frac{1}{2}$,,	$2\frac{1}{2}$,,

in cases where the ordinary porous-pot or agglomerate Leclanche cell was unequal to the duty required. The larger sizes of the sack cell now offer an alternative

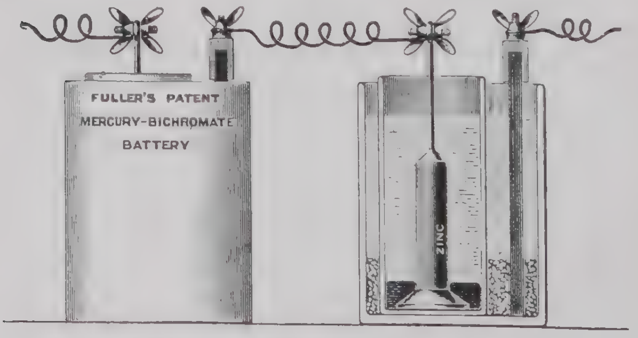


FIG. 79.

means of current supply and the Fuller cell is only used where exceptionally heavy and continuous demands are made on the battery, such as in shaft signalling installations. Two Fuller cells in series, one being shown in elevation and the other in section, are shown in Fig. 79. The elements of the cell are contained in an earthenware jar. Inside the jar is a

porous pot containing a zinc rod, which forms the positive element. The latter is a solid cylinder with enlarged cone-shaped base, as shown in Fig. 80. The object of the enlarged base is to compensate for the greater action which takes place at the bottom of the cell. Sometimes the coned part only is used, being cast on to a copper rod, as shown in Fig. 81, but solid zincs are to be preferred, as the fluid acts on the copper rod if not well insulated with a coating of gutta-percha. At the bottom of the porous pot is placed a quantity of mercury, which creeps up the surface of the zinc rod and thus keeps up the amalgamation of the rod. The negative element is a carbon plate, fitted with a brass terminal, which stands in the space outside the porous pot. The porous pot is charged either with plain water only or a solution of sulphate of zinc, in accordance with the internal resistance required of the cell. The outer jar is filled either with a solution of bichromate of potassium or of chromic acid to which sulphuric acid has been added. The original form of this cell is made in two sizes, particulars of which are given in Table X. on p. 94.

FIG. 80.

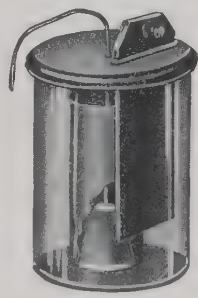


FIG. 81.

Chemical Charge for Fuller or Bichromate Cell.—As the internal resistance of the Bichromate cell

TABLE X.—SIZES AND PARTICULARS OF FULLER OR BICHROMATE CELLS.

Size of Cell.	E.M.F. in volts.	Internal Resistance in Ohms.	Weight in lbs. (without charge).	Overall Dimensions of Cell in inches.
No. 1 .	2·0	Standard 2 Maximum 3	—	$8\frac{3}{4} \times 5$
„ 2 .	2·0	„	—	$8\frac{1}{2} \times 6\frac{1}{4}$

varies with the strength of the exciting fluid, contained in the porous pot, the proportions of sulphate of zinc and water (used when an extremely low internal resistance is desired) may be varied to suit requirements, a solution varying from 10 per cent. to 50 per cent. is usually adopted. Plain water only is required for ordinary working conditions, the percolation of the depolarising solution through the pores of the porous cell supplying the necessary conducting medium. The depolarising liquid required for the outer containing jar may be made up in the following proportions :—

Potass. bichromate . . .	1 lb.
Concentrated sulphuric acid . .	2 lbs.
Water	11 pints.

The bichromate is dissolved in the water, which may be hot, and the sulphuric acid added to the resulting solution.

In diluting sulphuric acid, the acid should always be added to the water and not the water to the acid, as the resulting mixture may heat up to an excessive degree. For the same reason the mixing of acid and

water should always be carried out in a large earthenware jar; if glass is used the vessel is liable to crack. Precautions should be taken not to add too much acid at once to the solution, but time should be given for the liquid to cool. In place of bichromate of potassium, chromic acid may be used. This material will give more efficient results, as it is a better depolariser and dissolves almost instantly, giving a solution with a minimum of trouble, and does not give rise to troublesome crystals on evaporation. The chromic acid solution may be made up in the following proportions:—

Chromic acid	12 ounces.
Concentrated sulphuric acid . .	1 pint.
Water	11 pints.

The chromic acid should be placed in the mixing vessel, the water poured on to it and the sulphuric acid added gradually to the solution with constant stirring. From one to two ounces of mercury is placed in the porous pot along with the zinc rod.

Cells in Series.—The maximum voltage obtainable from a single ordinary primary cell is 2 volts, and in most instances a considerably less voltage is available at the terminals. From this it follows that a single cell is not of much use in practice, even for operating a single signal bell which usually requires not less than 4·5 volts. Where a current is to be transmitted through a long length of line wire the deficiency becomes still more pronounced, and in such circumstances, in order to obtain the increased voltage required, a number of cells must be joined together in series. This method of grouping cells is shown in Fig. 82, which represents three Leclanche cells con-

nected in this manner. In joining cells in series the carbon or copper terminal of one cell is joined to the zinc terminal of the next, and so on, whatever number of cells are to be employed, leaving a free carbon or copper terminal at one end of the battery and a free zinc terminal at the other end. Since the voltage of a Leclanche cell is about 1·6 volts, the addition of each single cell in series increases the total voltage by this amount ; thus in the example shown in Fig. 82 the

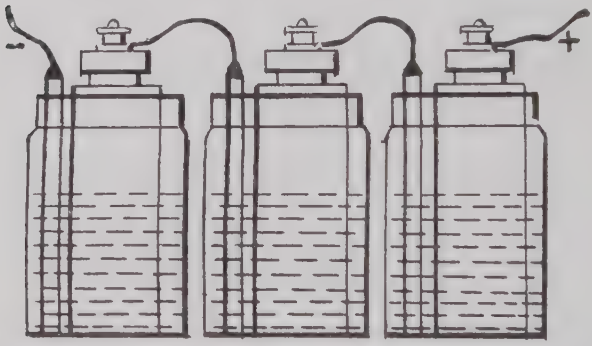


Fig. 82.

total voltage of the battery would be $1{\cdot}6 + 1{\cdot}6 + 1{\cdot}6 = 4{\cdot}8$ volts. It must be borne in mind, however, that in adding cells in series in this manner the internal resistance of the battery is also increased in proportion ; thus, if the internal resistance of a single cell is 0·8 ohm, the total internal resistance of the battery will be $0{\cdot}8 \times 3 = 2{\cdot}4$ ohms.

Cells in Parallel.—In some instances the internal resistance of a battery may be too high for the work it is required to perform, and it may not be convenient or

possible to obtain larger size cells. In such circumstances the battery may be grouped in parallel. In

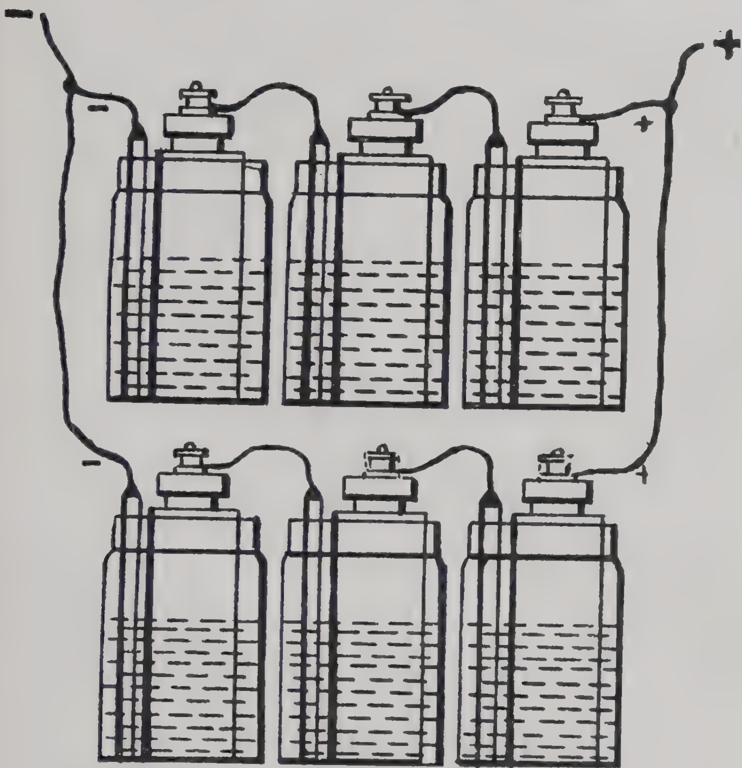


Fig. 83.

this method of arranging a battery, which is illustrated in Fig. 83, a sufficient number of cells are arranged in series to obtain the desired voltage, and two exactly similar sets are connected together in parallel, the two

positive terminals and the two negative terminals being connected together and to the line. The internal resistance is much reduced by coupling the batteries together in parallel in this way, thus enabling a larger current being taken from the battery. In the example shown in Fig. 83 the internal resistance would be only half that of a single battery. Although, as has been explained, it may sometimes be expedient to arrange the batteries in parallel, this should always, wherever possible, be regarded as a temporary measure, and cells of a larger size or those of another type better suited in capacity to the work the battery is required to perform should be substituted without delay. The reason for this is the fact that although any number of cells may be made up in exactly the same way and with the same materials, no two cells will have exactly the same voltage at their terminals, and if joined in parallel the cells possessing the higher voltage will drive a current through those of a lower voltage. This current, although it may be very minute, will nevertheless cause the battery to be constantly at work, and will eventually either exhaust the battery entirely or reduce its useful life considerably. A considerable amount of discussion has taken place in regard to this question, as to whether it is not more advantageous to use batteries composed of small size cells coupled in parallel, in preference to larger sized cells arranged as a single battery, but if the foregoing facts are taken into consideration there should be no two opinions concerning the matter. In those cases where some fancied advantage has accrued through the use of batteries of small cells coupled in parallel, this has been due to the larger size cells provided for comparison not

being sufficiently large enough so as to equal the internal resistance of the smaller cells when coupled in parallel. There are certain circumstances, such, for example, as in some systems of engine plane signalling, where the use of batteries in parallel on the line circuits cannot be avoided, but these instances can only be regarded in the light of a necessary evil, often giving rise to considerable trouble if the batteries are not frequently inspected and attended to.

Electro-motive Force of Signal Batteries. — The number of cells in series (on which depends the voltage of the signalling circuit) required for any particular installation will vary according to circumstances. So many different conditions of size and length of line wire, age of battery cells, character of insulation and the nature of the working places in which the signalling apparatus is fixed, are involved in the question that it is impossible to give any definite rule. The exact number of cells required in any given instance can only be definitely ascertained by trial under working conditions. It is always advisable to have plenty of battery power available, as there is no more frequent source of trouble with mining signals than having too few cells in the battery. It is frequent practice in large mine signalling installations to install duplicate sets of batteries, one set being kept in reserve and used occasionally, allowing the other set time to recuperate. In the case of fiery mines the voltage of the signalling circuits is by special mining rules limited in Great Britain to a maximum of 25 volts. This voltage is equivalent to that of sixteen Leclanche cells or twelve Fuller cells in series. Quite apart from any question of compulsory regulations this voltage

forms a very convenient maximum for mining signal installations, owing to the freedom from shocks in operating the apparatus and to the fact that a satisfactory working insulation can be maintained without special precautions being necessary.

Setting up Primary Cells.—Before proceeding to set up a primary battery, it is first of all necessary to decide upon the most suitable position in which to place it. A cool, dry position is best, but the battery should not be placed too far away from the bells or ringing keys in order to secure this advantage. For easy inspection and cleanliness the battery should be kept in a strong wood box or cupboard with shelves just deep enough for one cell and a narrow strip of wood 1 inch $\times$ $\frac{1}{4}$ inch between each to separate the cells and prevent surface leakage. The top of the cupboard should be made to slope to the front at an angle of about 45 degrees, so as to prevent its being used as a seat or as a receptacle for oil cans or lamps, any oil or other greasy substance which may drip through will soon spoil the cells entirely or cause bad contacts at the terminals. A few holes should be bored in the bottom of the cupboard to allow a certain amount of air to enter, and also to allow any liquid to drain away which might perchance be spilled in the charging process. The cupboard should be provided with one or two doors arranged to open at the front and hinged on the sides of the cupboard. This allows of easy inspection of the cells. If the lid or top is made to lift, as sometimes is the case, it is not possible to ascertain the height of the liquid in the jars without removing them from the box or cupboard. It is always best to have a switch fixed as near to the battery as possible, either inside the cup-

board itself or near at hand, so as to be able to disconnect the carbon pole of the battery during the night and at other times when signals are not required. This prevents unnecessary leakage and increases the life of the battery.

Setting up Leclanche Cells.—In setting up these cells the sal-ammoniac in the quantities specified for the various sizes is placed in the glass jar and enough water added to come about half-way up the jar. The carbon and zinc elements are then inserted, and if a porous-pot is not employed the cell is ready for use almost immediately. If the cells are of the original porous-pot form the solution will diffuse but slowly through the porous earthenware, and the battery will not be ready for use until the next day, but it will expedite matters if some of the solution is also poured down the vent tubes. It is the practice with some fitters to bore holes or make saw cuts in the bottom of the porous pot, and thus put the cell into action without any delay, but this practice is not to be recommended, as the pulverised contents of the porous pot escape into the bottom of the jar and eventually reach the zinc setting up local action and speedily exhausting the battery. In setting up a battery care should be taken not to splash any liquid into the brass terminals, or corrosion will result, also if any is spilled over the edge of the glass jar it may occasion *creeping* of the sal-ammoniac.

Setting up Fuller or Bichromate Cells.—These cells are set up by first placing the porous pot containing the zinc rod and necessary quantity of mercury required for amalgamation in the proportion of two ounces for each quart cell into the glass or earthen-

ware outer jar. The porous pot is then filled up to within an inch of the top with a solution of either sulphate of zinc or plain water as may be decided upon as being the most suitable for the work the battery will be required to perform. The depolarising liquid is prepared in accordance with the formulæ given on p. 94, and when cool it is poured into the outer containing jar until the level of the liquid is about $1\frac{1}{2}$ inches from the top of the jar. The carbon plate is then placed in position and the cells connected up. It is important to adjust the level of the liquid in the porous pot so that it is higher than that in the outer jar, as otherwise the depolarising liquid will quickly diffuse through the porous partition and act upon the zinc to an excessive degree. The water used for charging all forms of primary cells should either be distilled or rain water and preferably used in a heated condition in order to dissolve the various salts as quickly as possible.

Maintenance of Primary Batteries.—In order to avoid the inconvenience and annoyance caused by the unexpected failure of a battery to perform its duties and to ensure that it remains in a reliable condition at all times, it is necessary to make inspection of the battery at frequent intervals. Each of the cells composing the battery should be tested with a low reading voltmeter, and if any particular cell gives a lower reading than the normal or below that of the rest of the cells it should receive special attention. If the elements are at all worn or exhausted they must be renewed. If the zincs are only slightly pitted and a substantial thickness remains, they may be restored to a good working condition by scraping clean and reamalgamating them. If much corroded, however, the

best course is not to waste time in endeavouring to restore them into working condition, but to supply new ones entirely. The electrolyte will also require attention ; if exhausted the battery will need to be recharged entirely, but if the liquid has only evaporated it may be restored to its original level by the addition of water. If when recharging a battery it is necessary to remove the porous pots, they should be kept, when not in use, in water to prevent crystallisation of the exciting salts in the pores and subsequent disintegration. All metal surfaces where contact is made must be kept bright and clean, and all screws and nuts and terminals holding wires must be screwed up tight so that the wires are firmly clamped.

Amalgamation of Zinc Element.—If rods and plates of ordinary commercial zinc are used as the negative element in a primary battery they will quickly become eaten away in holes and otherwise much corroded, even if the battery is not in use. This uneven working causes surface incrustation, local action, and great loss of effective capacity of the battery. The removal of the incrustation, which must frequently be done, is costly, and is seldom properly performed, the crystals and general incrustation being extremely difficult to remove. The result is an all round reduction in working efficiency and length of life of the battery. A most effective means of preventing this corrosion of the zinc element is by the process of *amalgamation*. This is readily carried out by immersing the zinc rods or plates in dilute sulphuric acid, which may be contained in a shallow porcelain dish or similar vessel. A small quantity of mercury is then poured on to the zinc which is rubbed with a mop made by wrapping a

woollen rag around the end of a stick. The solvent action of the acid chemically cleans the surface of the zinc which becomes covered with a bright coating of mercury. In this condition the zinc is no longer attacked by the acid or other fluid notwithstanding any impurities which may be present, and the surface will always remain bright and clean so long as the amalgamation is kept up and the battery will attain a much increased efficiency and useful life.

Maintenance of Leclanche Cells.—A Leclanche battery when once set up will, under ordinary conditions, require little attention and will work without re-charging for a period varying from three to twelve months according to the size of the battery and the nature of the working conditions. It is best, nevertheless, not to await until the battery shows signs of exhaustion, but to inspect it at frequent intervals varying from once a week to a month to ensure reliability in working. If the zincs are black and a strong smell of ammonia is given off by the battery, it denotes either excessive working or leakage or an actual short circuit somewhere. If due to the latter cause the defect can be located with a galvanometer or lineman's detector, and remedied and the battery will then need to be re-charged. If the insulation is good and the battery is apparently too small for its work, it will be necessary to replace the cells with a size larger or substitute some other type of battery cell more suited to the conditions of working. Leclanche cells may often be seen with an excess of sal-ammoniac crystals at the bottom of the glass jar, but this is an objectionable practice as it tends to cause a deposit of crystals on the surface of the zinc which interfere with the

working and action of the cell. These crystals, which consist of a double chloride of zinc and ammonia, are transparent and of a needle-like form, and are very hard and in most cases adhere very firmly to the zinc so that some difficulty is found in removing them. If not able to scrape the zincs clean ready for re-amalgamation, new zincs should be substituted. The formation of these crystals is avoided if the correct amount of sal-ammoniac as specified is used in charging each size and pattern of cell. In cases where reliability is the primary consideration, and the zincs show signs of wear, it is best to re-charge the battery entirely with new solution and substitute new zincs for the old ones. Unless subjected to excessive working or short-circuiting the charged porous pots or agglomerate blocks will not require frequent renewal. If any salt is discovered to be creeping over the top of a jar, the faulty jar should be removed, washed and well dried and the top dipped in either melted paraffin wax or ozokerite. If not convenient to dip the glass jar in this way the neck may be cleansed from any adherent crystals and rubbed with tallow or grease which forms a good substitute. In order to prevent creeping of the salt up the heads of the carbon plates they should be occasionally coated with Brunswick black varnish.

Maintenance of Fuller or Bichromate Cells.—This cell can be allowed to stand on open circuit for several months at a time without any appreciable depreciation. The cells must be filled up with water from time to time as the level of the liquid falls owing to evaporation. The original colour of the depolarising solution is orange, but the colour changes as it becomes exhausted during working. When it becomes bluish in colour more

crystals of bichromate of potash or chromic acid should be added. Should the colour be normal and the cell weak add fresh sulphuric acid. When the solution becomes greenish and muddy in appearance, it is an indication that it has become exhausted and the battery should be entirely re-charged.

CHAPTER VII

ELECTRIC MINING SHAFT SIGNALS

THE question of shaft signals is one of great importance in mining, as on the efficiency of the system depends the whole output of the mine, since they control the winding operations. The design of a suitable electrical system applicable for each particular case therefore requires careful consideration. The principal points to be kept in view in preparing a scheme of wiring and in selecting apparatus for this purpose are simplicity and reliability, and, while having due regard to securing the utmost rapidity in signalling, the transmission of distinct and definite signals is essential, in order to avoid the risk of accidents occurring through a confusion of signals.

Methods of Shaft Signalling.—A number of different methods of arranging electric shaft signals are available and the best to adopt in any particular instance will depend upon the special conditions of working, and the number of levels or seams, etc., in the shaft. The usual practice, in colliery working, is for the onsetter at the bottom of the shaft, or at the different levels, to transmit the signals to the banksman, who then signals to the engineman; but an alternative system is also employed, whereby the signals are received simultaneously by both banksman and engineman. In the

former system an additional circuit is used solely for the purpose of signalling between the banksman and engineman. This signalling circuit may be entirely separate and distinct, or it may be operated by the same battery as the shaft signalling circuit. In the latter arrangement the signal bells at bank and engine house are rung simultaneously and may advantageously be connected in series for the sake of simplicity in wiring and certainty in action. Either single-stroke or trembling bells may be employed with this arrangement, but if trembling they should be of the shunt or differential type, in order to secure reliable signalling. If the bells are connected in parallel an element of uncertainty is introduced, and it is possible that the bells will not ring simultaneously, leading to false signals being received. In regard to the selection of suitable ringing keys, it may be pointed out that the use of the common Morse or return signalling key forms a dangerous feature in connection with shaft signalling, as should both banksman and onsetter happen to signal to each other at the same moment neither signal will be received. This may lead to false signals being given and received, and for this reason a simple circuit-closing device is to be preferred. The only advantage appertaining to the use of Morse keys is the fact that a less number of line wires are required in the shaft to work the system.

Arrangement of Shaft Signalling Battery.—There are two methods of arranging the battery required for use in operating a shaft signalling system, viz., the *central battery* and the *multiple battery* systems respectively. In the first-named system a single battery only is employed, of a size sufficiently large to operate the

whole of the shaft signals, both at bank and at the different levels or seams. This battery is fixed in some convenient position on the surface, usually in the engine house or similar dry situation. In the second, or multiple battery system, a number of independent batteries are employed, corresponding to, and placed at the various transmitting stations in the shaft and on the surface. The central battery system has much to recommend it if the special conditions prevailing are favourable to its adoption. The cells are then easy of inspection and, being placed in a position free from the various detrimental influences frequently met with in shafts, such as the presence of wet and dirt, etc., the cells are not likely to deteriorate, and the battery consequently requires less attention. The chief objection to the central battery system is the fact that if any serious fault develops, either in the wiring or in the battery itself, the whole of the signalling system may be temporarily rendered idle until the fault is located and remedied. Another disadvantage, peculiar to the system, is that the full battery pressure is always present in the shaft wiring since the two battery leads are taken down the shaft to enable the onsetters at the different levels to ring up to the surface, and this may lead to electrolysis and leakage, or short circuiting of the battery if the insulation of the shaft wiring becomes defective. With a multiple battery system both of these troubles are almost entirely absent, since the failure of one battery will not necessarily affect the working of the remainder, and, as no difference of pressure exists in the shaft wiring, except at the moment when a signal is being transmitted, the effects of electrolysis and leakage are greatly minimised. On the other

hand, the multiple battery system, which requires a set of cells, or a separate battery, at each signalling station, necessitates more cells and more time to attend to them. It may be said generally that where the mineral is being raised from more than one level the multiple battery system gives the greater safety in working.

Shaft Signal Wiring Diagrams. — In preparing a scheme of shaft signal wiring, every mine requires to be considered on its own particular merits. The diagrams (Figs. 84 to 93) show the arrangements which are most commonly required in connection with electric shaft signals. Special requirements can generally be met without departing from the use of standard accessories by a suitable modification of the wiring diagrams. As in nearly all cases water or other metal pipes are present in the shaft, a strong temptation exists to utilise these, or the ground, as a return conductor in place of an insulated return wire, but except in certain favourable circumstances, it is of vital importance that all current-carrying parts of electric shaft signalling apparatus should be thoroughly insulated from the ground. The use of an earth or ground return not only introduces an element of uncertainty into the signalling system, but instances have occurred where the signal bells, relays, etc., have become energised by stray currents from a distant tramway or other high tension earthed return system, and this effect is sometimes further contributed to by differences in the electrical conductance of the various strata forming the shaft.

Morse Key Signalling Circuit (Fig. 84).—This arrangement forms the simplest of all the various electric

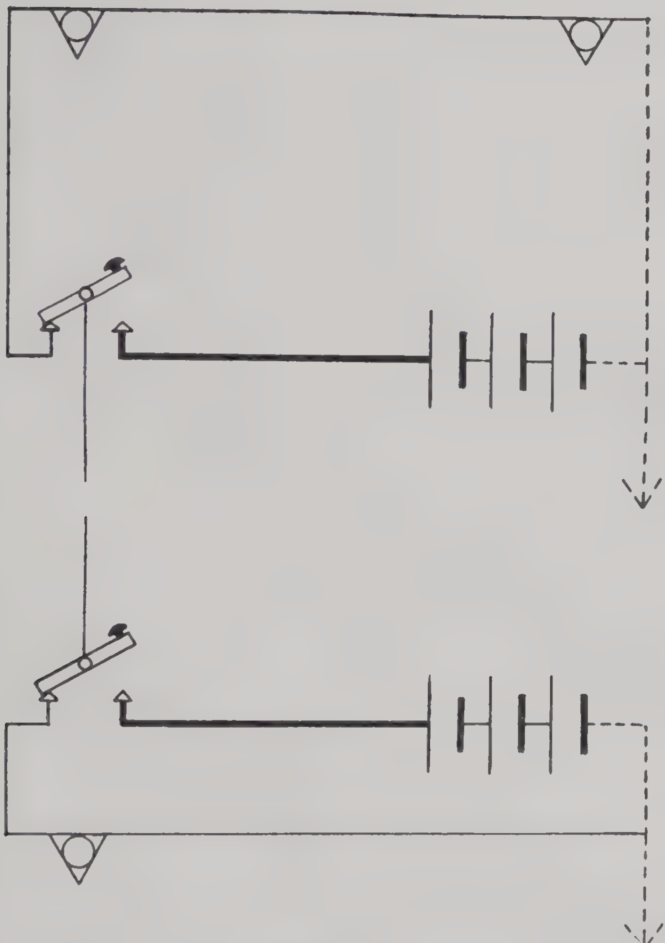


Fig. 84.

signalling systems. If an earth return is used, only one wire is required in the shaft to operate the system.

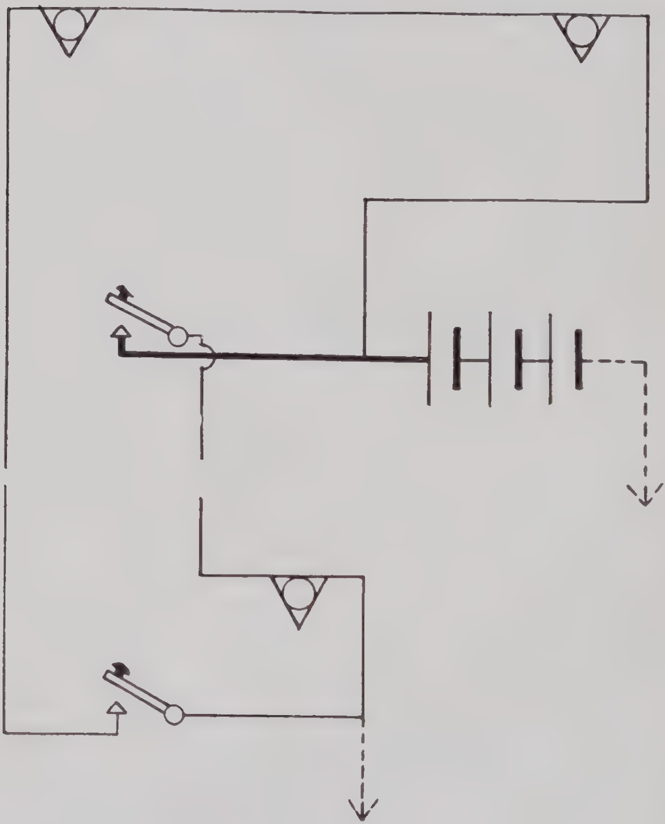


FIG. 85.

Two ordinary Morse or return signalling keys and two separate batteries to operate them are required, one being placed at the top of the shaft and one at the

bottom. Three signal bells are shown as being fitted, one at the bottom of the shaft for signalling to the onsetter stationed there, one at the top of the shaft

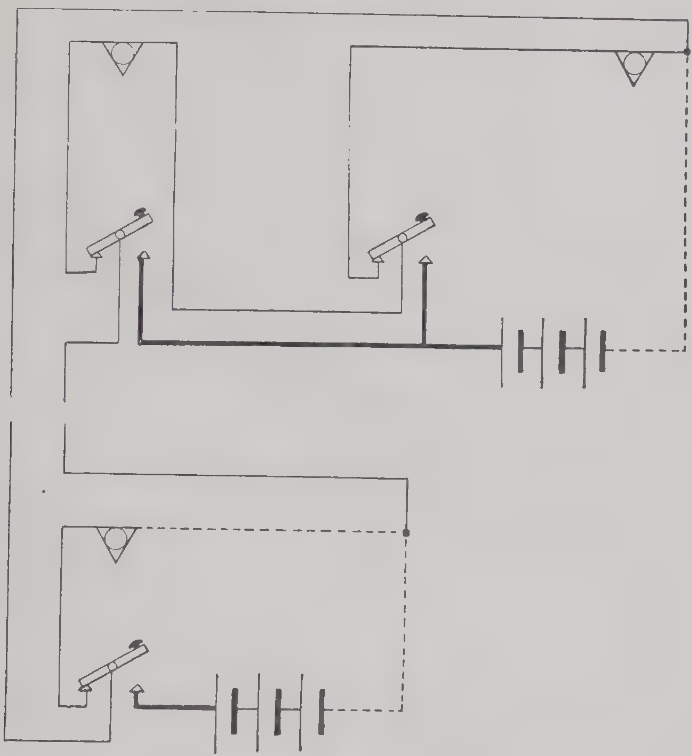


Fig. 86.

in the banksman's cabin, and one in the engine house on the surface. As no key is provided in the latter position, it is only possible for the engineman to receive and not to send a signal. This simple arrange-

ment forms the basis of all other Morse key shaft signalling systems, it being suitably elaborated to suit the different conditions of working.

Plain Tapper Key Signalling Circuit (Fig. 85).—In this arrangement of the wiring, plain circuit-closing devices, or tapper keys, similar in principle to ordinary bell pushes, are substituted for the Morse keys as used in Fig. 84. A single battery only is required, this being placed in the engine house at the top of the shaft.

Morse Key Signalling Circuit (Fig. 86).—In this instance the engineman is provided with a Morse key enabling him to send and receive signals. The onsetter at the bottom of the shaft signals to the banksman and engineman simultaneously; the engineman signals to the banksman and onsetter also simultaneously, while the banksman can signal to the onsetter only. The batteries, of which two are required, are arranged upon the multiple battery system, one battery being placed at the top of the shaft and the other at the bottom. Only two wires are required in the shaft to operate the system.

Morse Key Signalling Circuit (Fig. 87).—In this arrangement of the wiring the banksman and engineman, on the surface, can each signal independently to the onsetter at the bottom of the shaft. In return the onsetter can only signal to the banksman and engineman simultaneously. The signals are worked on the central battery system, three wires being necessary in the shaft.

Morse Key Signalling Circuit for Three Seams or Levels (Fig. 88).—This forms the simplest system of signalling for three or more seams or levels, and can

be carried out with the least number of wires in the shaft. The banksman can signal to any of the seams

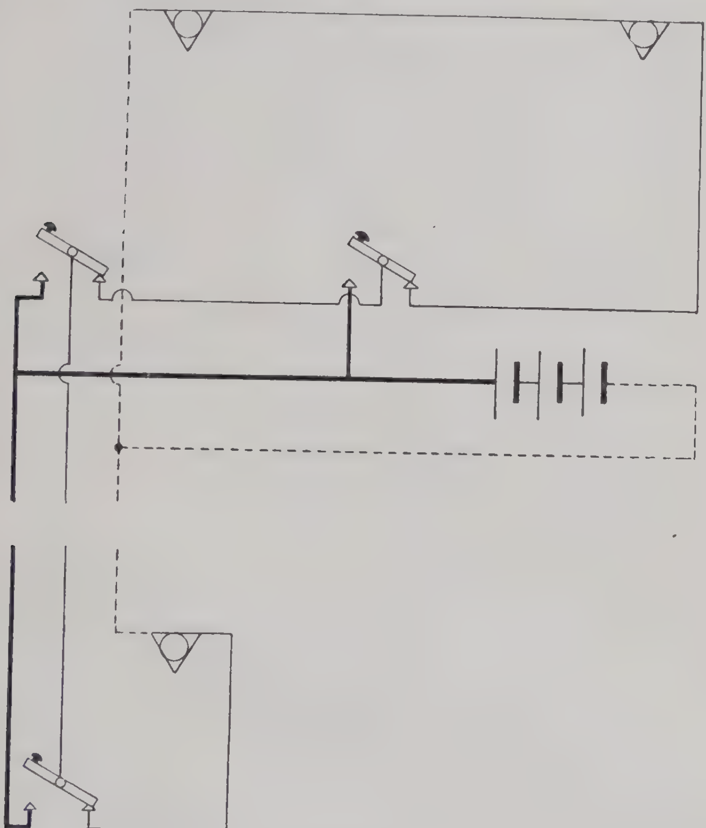


FIG. 87.

or to the engineman independently. The onsetters at any of the seams can each signal, independently,

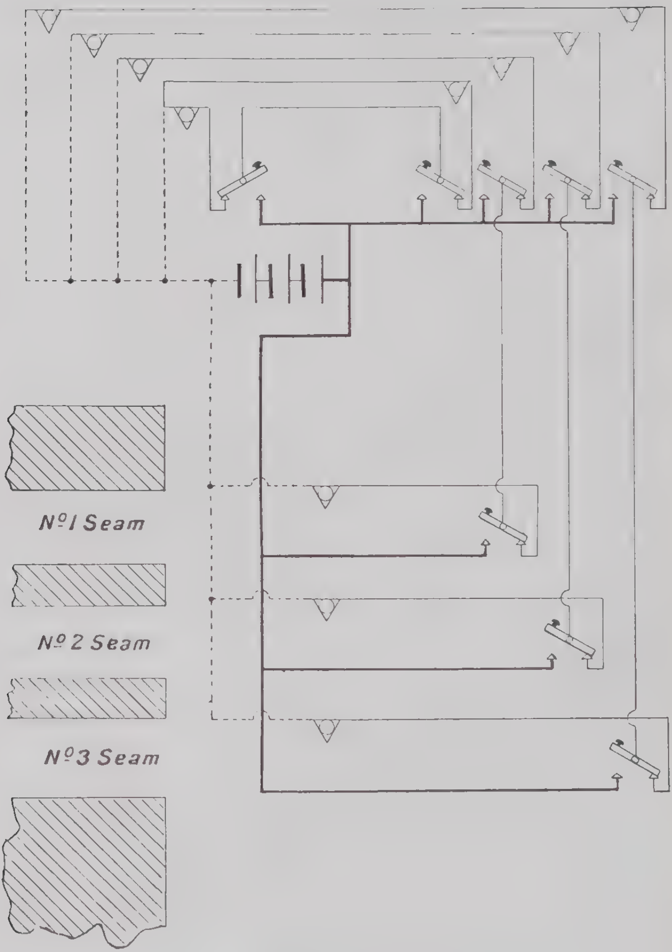


FIG. 88.

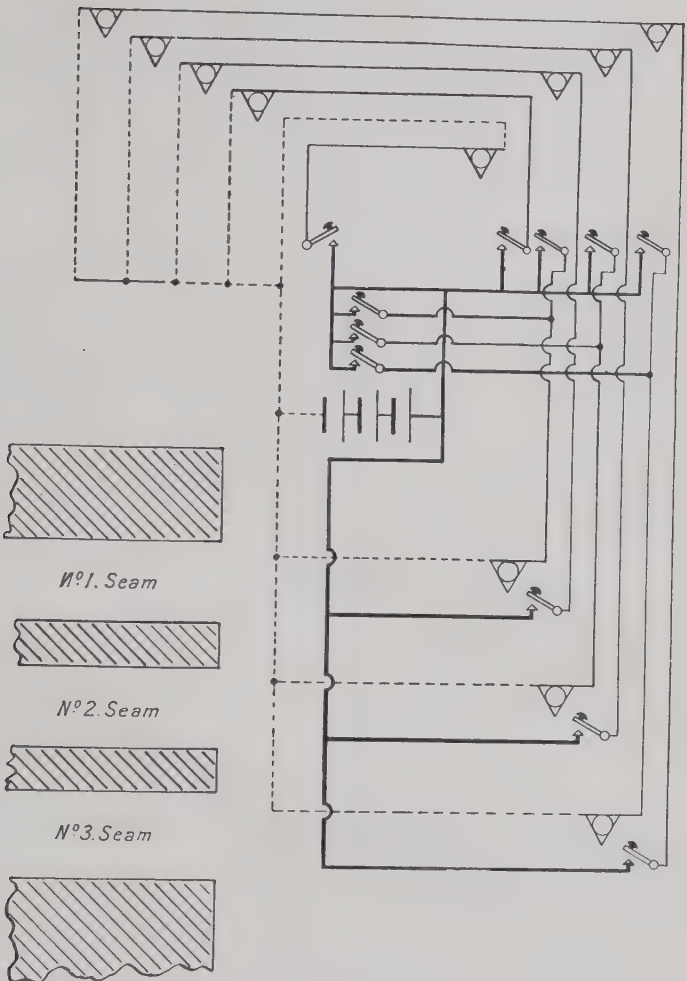


FIG. 89.

to the banksman and engineman simultaneously, while the engineman can signal to the banksman only. The signals are shown as being worked on the central battery system, but they may be adapted for multiple battery working, if desired, by placing a ringing battery at each of the levels. This latter arrangement will necessitate a single wire less in the shaft than the former.

Plain Tapper Key Signalling Circuit for Three Seams. Central Battery System (Fig. 89).—In this system plain switch pushes or tapper keys are employed throughout to transmit the signals. Each of the onsetters at the different levels is provided with a ringing key and each can transmit a signal to the engineman and banksman simultaneously. The engineman and banksman can each transmit signals to the different levels, independently, and they can also signal to each other. A separate signal bell for each level is shown as being fixed in the engine house and banksman's cabin on the surface, but in place of these, indicators may be fitted to show from what level a signal comes, and bell signal indicators (Fig. 47) may also be arranged in series with the signal bells in the engine house, to indicate the number of strokes or rings of the bells.

Plain Tapper Key Signalling Circuit for Three Seams or Levels. Multiple Battery System (Fig. 90).—This diagram is the counterpart of Fig. 89, but the signals are arranged to work on the multiple battery system. As will be seen, a separate battery is provided for each seam or level, and also one on the surface for use by the engineman and banksman in transmitting signals. This arrangement probably forms the most perfect

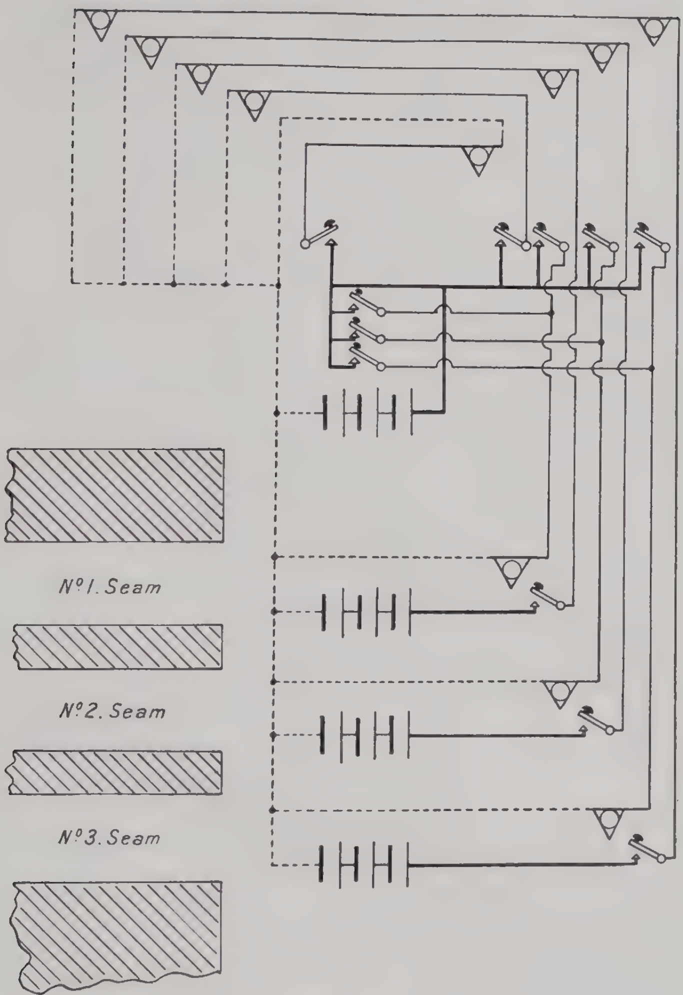


Fig. 90.

and reliable of the various shaft signalling systems at present in use. It will be noted that the full battery

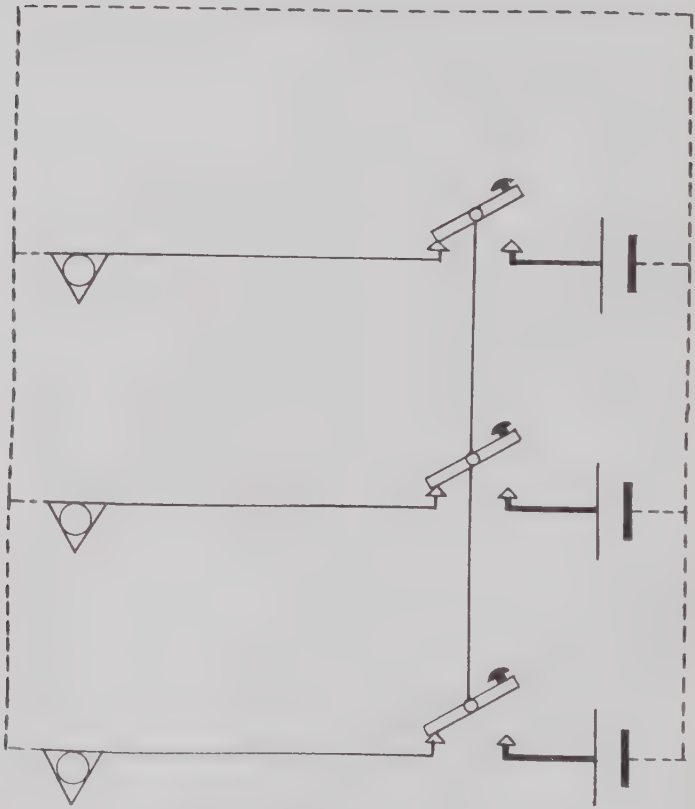


Fig. 91.

pressure is only put on to the lines at the moment when the signals are being transmitted; and thus the electrolysis and other leakage troubles are minimised

to the greatest extent. The system possesses other excellent features; for example, if one of the ringing

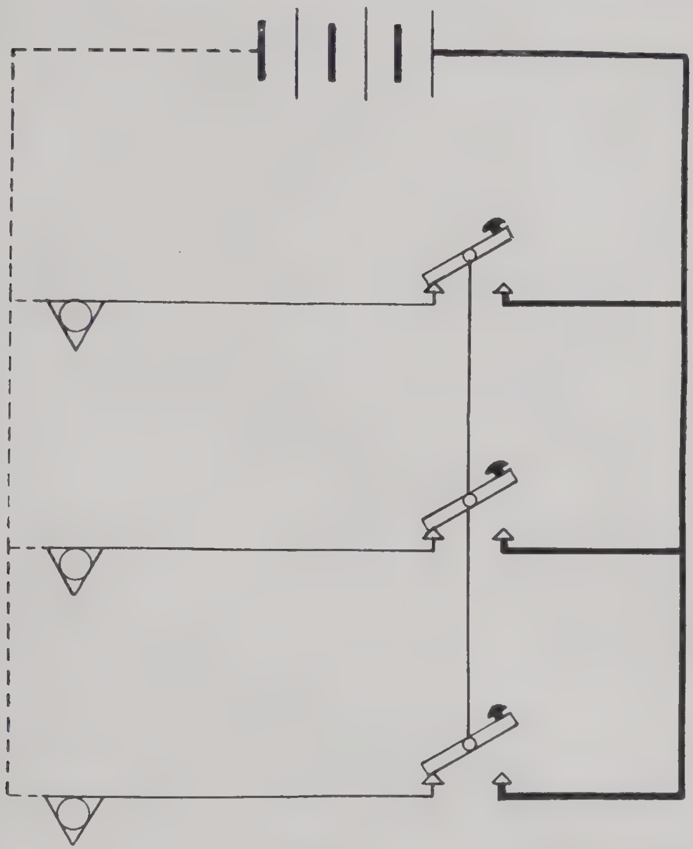


FIG. 92.

batteries fails, it need not necessarily stop or otherwise interfere with the working of the whole of the shaft

signals, as would happen in the case of the system shown in Fig. 89, but only the working of the seam where the faulty battery is located would be affected. The system may be adapted for working a single level only or it may be elaborated to almost any extent by making suitable modifications in the wiring diagram.

Morse Key Signalling Circuit for Three Levels. Multiple Battery System (Fig. 91).—This arrangement of the wiring enables any number of bells being rung simultaneously, except the one at the level from which the operator transmits the signal.

Morse Key Signalling Circuit for Three Levels. Central Battery System (Fig. 92).—This diagram illustrates the arrangement of the connections for working the signalling system shown in Fig. 91 by means of the central battery system.

Morse Key Signalling Circuit for Three Levels (Fig. 93).—To ring all the bells above the level from which a signal is being transmitted, without ringing the lower ones, while the banksman at the top of the shaft can ring the bell at the bottom of the shaft without ringing those at the intermediate levels. The ringing key at the top of the shaft is a plain circuit closer or bell push, the other ringing keys are ordinary Morse keys arranged for sending and receiving signals.

Visual Electric Shaft Signalling Apparatus.—The constant endeavours now being made to speed up the winding arrangements of mines and to increase their outputs to the maximum possible, while at the same time safeguarding the lives of the workmen and preventing risk of damage to the mining equipment, has led to the introduction of a number of specialised systems of electric shaft signalling. The object of all

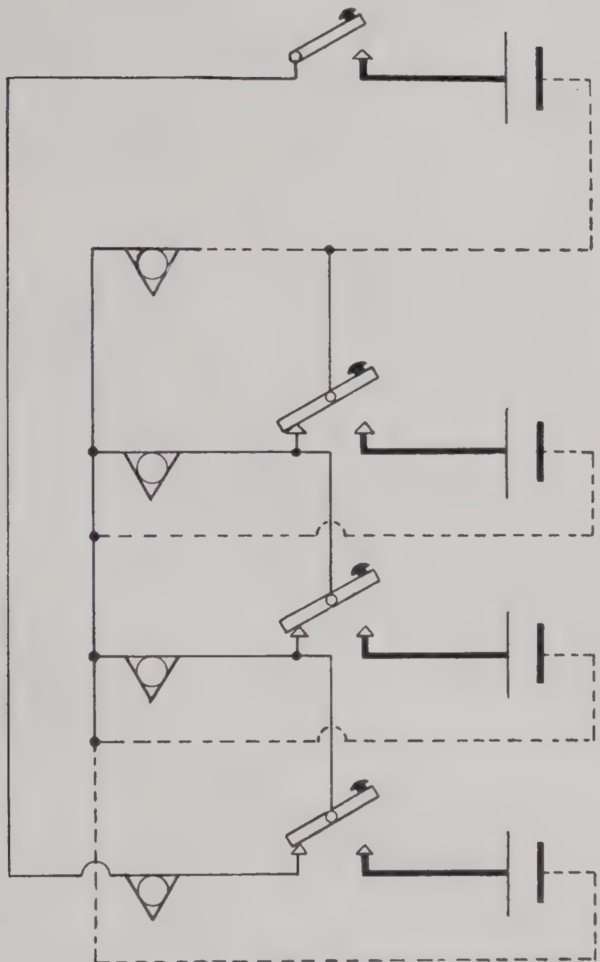


FIG. 93.

of these systems, which are more or less elaborate, is to provide a more effective means of signalling than is possible by the use of a bell or other audible signal device alone. The most prominent feature of the various systems is the device for indicating the nature of the signal or order being transmitted from the sending to the receiving station. This indicator, in nearly all cases, is either provided with a pointer or hand moving over a numbered or lettered dial, or else electric incandescent lamps are used which illuminate the dial from behind. The face of the dial being transparent and the various orders being painted thereon in opaque letters, or *vice versâ*, the signal indications are easily read off. As an additional precaution, and in order to render the risk of accidents as small as possible, most of these signalling systems are used in conjunction with the ordinary bell signalling installation, so that both audible and visual signals are transmitted, and thus one system corrects and confirms the other. As apparatus of this description requires a comparatively large current to operate the system, ordinary primary batteries are not suitable for the purpose. The method of providing the current required varies according to circumstances. Where the mine is equipped with alternating current, a transformer is installed for reducing the pressure to the required maximum voltage, viz., 25 volts, and where direct current is used a small motor generator is usually employed. An accumulator battery charged from either alternating or direct current mains may also be used for the purpose.

Siemen's Luminous Mine Shaft Signalling Apparatus.—This apparatus has been designed to provide a safe and rapid means of communication of orders from the

different levels of the mine to the engine house, by the addition of visual indications of the orders to the bell signals usually employed. The apparatus consists of sets of indicators and bells for the bank of the mine, engine room, and levels. These parts are illustrated by Figs. 94, 95 and 96 respectively, and the method of working them is as follows: When it is required to

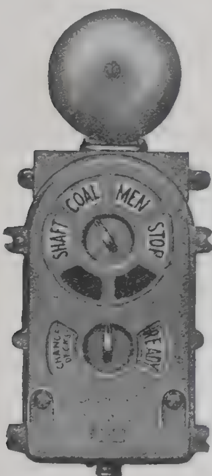


FIG. 94.

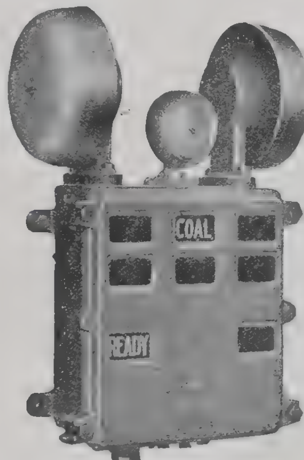


FIG. 95.

wind men from the level the onsetter turns the top switch on his indicator to "men," and then gives the customary rings on the bells at the bank and engine house by means of the bell switch provided. If the banksman concurs with the signal from the onsetter, he replies by means of the bell and turns his switch to "men," whereupon the signal "men" is illuminated in the engine house, at the bank, and at the level.

This indicates to the engineman that men are to be carried, and this order remains in force for all the subsequent windings until altered for some other operation, such as "coal" or "shaft."

The operations of winding are controlled by the lower switches on the bank and level instruments in the following manner: If the cages are provided with one deck only, and are loaded ready for raising and lowering, the onsetter and banksman turn their respective switches to "ready," and give the usual rings on the bells. When both have turned their switches, the signal appears illuminated at the engine house, bank, and level. It will be seen that the visual indication of the order does not appear in the engine house until both the onsetter and banksman are ready for the order to be executed. When the engine has started, a switch is actuated which releases the "ready" switches at both the bank and level, thus extinguishing the lamps and the order on the indicators and leaving them clear for further orders. In cases where the cages have two or more decks which are loaded from one staging, necessitating the moving of the cage a short distance after one deck has been loaded, the operation is controlled by turning the switch to "change decks," with the same procedure as for "ready." The signal "change decks"

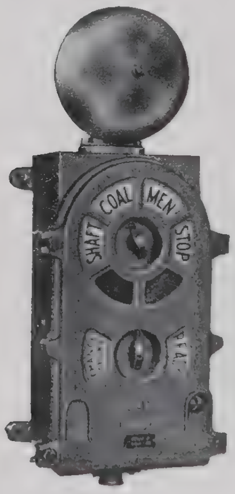


FIG. 96.

is obliterated by the movement of the engine in the same manner as the order "ready." When all the decks are filled, the signal "ready" can be given in the same manner as for one-deck cages as described above. Any system of bell signals can be used in conjunction with the luminous signals. The circuits for illuminating the indicators being separate from the bells, the indicators form independent corroboration of the bell signals, and as it is necessary for both the onsetter and banksman to operate their switches before the orders are illuminated, it is clearly indicated to the engineman that he may proceed without any possibility of doubt as to the bell signals given. The emergency or "stop" signal can, however, be operated independently by either the onsetter or banksman to stop the cage at any point. An important feature of the system is that the apparatus can be installed without interfering with any existing system of signal bells which can be operated in the ordinary manner, the apparatus being supplied with or without bells according to circumstances. In addition to the safety provided by having a visual indication of the order, further security is obtained by the arrangement that the visual signal indication does not appear until both the men concerned, the onsetter and the banksman, have concurred and performed their part of the signalling. It is also impossible for more than one order to appear at the same time, the changing of an order by either man extinguishing automatically the previous indications. Visual indications are provided by illuminated windows, on which the orders appear as soon as the lamps which are arranged behind them are lit by the operation of the switches at the levels and

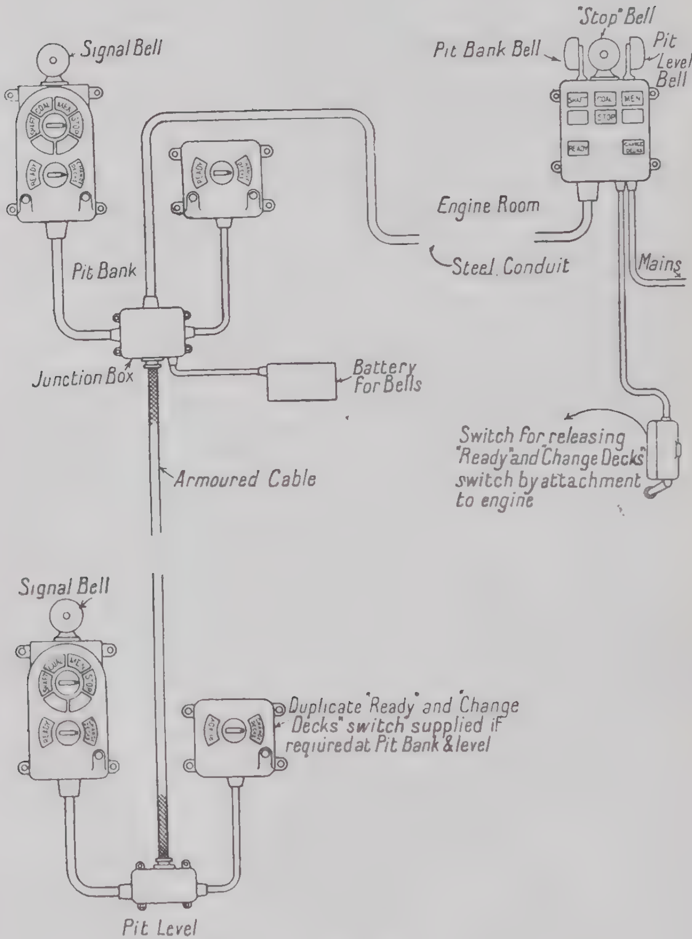
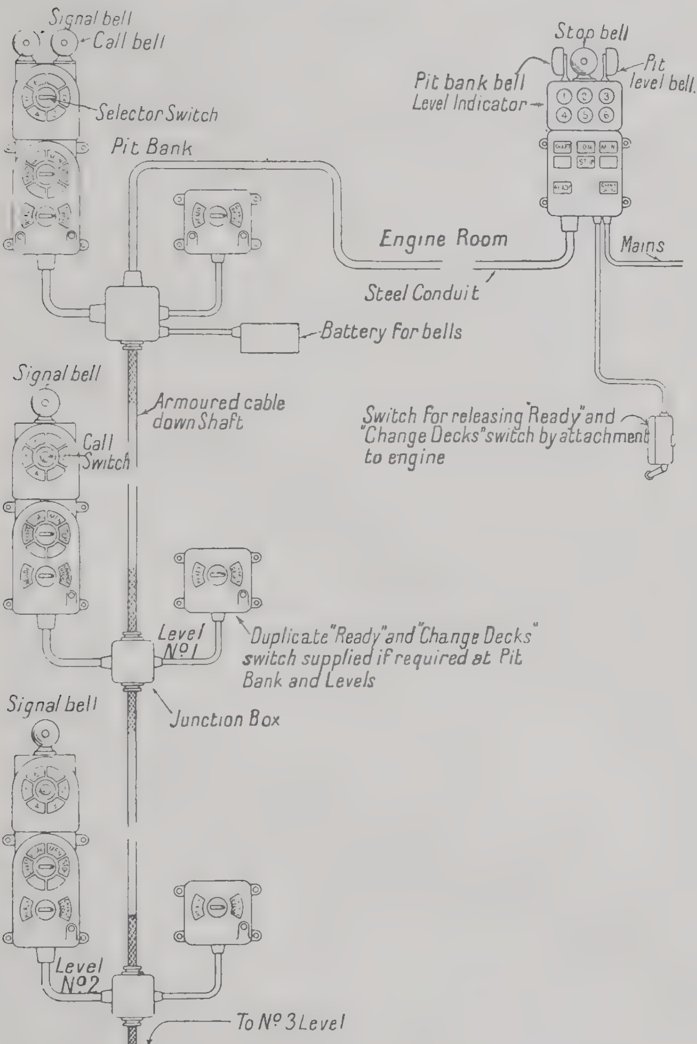

Signal Bell
"Stop" Bell
Pit Bank Bell
Pit Level Bell
SHAFT
COAL
MEN
STOP
READY
CHANGE DECKS
Engine Room
Pit Bank
Steel Conduit
Mains
Junction Box
Battery For Bells
Switch for releasing "Ready" and Change Decks" switch by attachment to engine
Armoured Cable
Signal Bell
Duplicate "Ready" and "Change Decks" switch supplied if required at Pit Bank & level
Pit Level

FIG. 97.



Signal bell
Call bell
Selector Switch
Pit Bank
Stop bell
Pit bank bell
Pit level bell.
Level Indicator
Engine Room
Mains
Steel Conduit
Battery for bells
Signal bell
Armoured cable down Shaft
Call Switch
Switch for releasing "Ready" and "Change Decks" switch by attachment to engine
Level No. 1
Duplicate "Ready" and "Change Decks" switch supplied if required at Pit Bank and Levels
Signal bell
Junction Box
Level No. 2
To No. 3 Level

FIG. 98.

at bank. Although the bell signals are independent of the luminous indicators, practically no time is lost in working the latter, since it only requires the operating of the " ready " switch at each winding. The moving of the switch for the standing orders is only required at long intervals. The " stop " or emergency order, when operated at either the bank of the mine or the levels, immediately illuminates the order on all instruments and at the same time rings a trembler bell in the engine house. For this signal it is not necessary for the onsetter and the banksman to operate their switches together, as in the case of the other standing orders. For mines in which there are two or more levels from which it is required to communicate with the engine house, additional sets of indicators are installed under the control of the banksman, to indicate to the onsetters which level to use, and to the engineman to which level to work the cage. Means are also provided in this apparatus whereby only the level to which the cage is working can send orders to the engine house. Each onsetter can communicate to the banksman in order to indicate when he requires the cage to stop at his level. The apparatus is contained in substantial watertight cast-iron cases with separate windows for each order. The press switches and the order-sending switches are securely protected, so that it is impossible for them to be accidentally closed. The diagram (Fig. 97) shows the general arrangement of the apparatus for a shaft having one level only, and Fig. 98 that for a shaft having two or more levels. The bells shown on the apparatus in the latter diagram are arranged so that only that level to which the level indicator at the bank of the mine indicates is able to send signals. A special bell is

provided at the bank, however, which can be rung at any time from the other levels to draw the attention of the banksman that they require the cage to work to their level. In cases where it is necessary to work the cages from either side of the shaft, duplicate " change

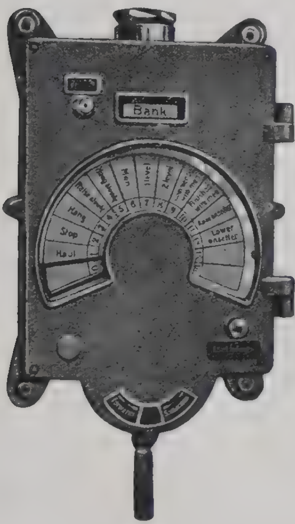


FIG. 99.

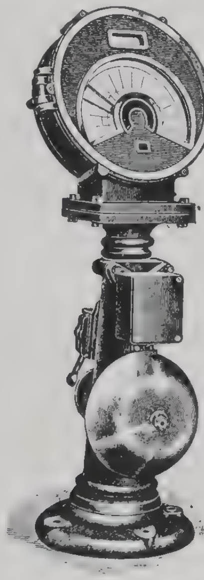


FIG. 100.

decks " and " ready " switches may be fitted as shown in the diagrams (Figs. 97 and 98).

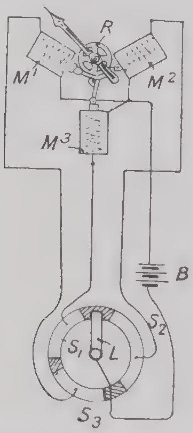
" Adnil " Luminous Mine Shaft Signalling Apparatus.—An interesting apparatus which has been designed to assist in the safe operation of winding in mine shafts is the " Adnil." This system combines the usual audible bell or hooter arrangement with an indicator

showing in plain letters and figures to the onsetters at the various levels in the mine, the banksman and the engineman, exactly what signals have been given. An instrument (shown in Fig. 99) which serves both as transmitter and receiver is installed at each level and at the surface. The winding engineman has a receiver only, of the type shown in Fig. 100. All these places have an acoustic signalling instrument (electric hooter or single-stroke bell). In the engine house is placed the central contact apparatus, to which all instruments are connected. On each instrument a "level indicator" is provided. This shows from which level the signal has been transmitted, and by a special contrivance it is rendered impossible for a signal to be given from any other point than that indicated. Should it be necessary, however, for a signal to be transmitted from a different level to that shown by the indicator, this can be done by automatically altering the indicator by means of a special push which is fitted for the purpose. The alteration takes place simultaneously on each instrument, and at the same time the acoustic signal on each instrument is sounded, thereby drawing the attention of everybody concerned to the alteration. The transmission of signals is carried out in the following simple manner: If a winding signal has to be given from any particular level—say on No. 1 level—the onsetter would, first of all, by depressing the level indicator push, cause the signal "No. 1 level," to appear behind the small glass pane immediately above the dial of his instrument. He then moves the lever, shown below in Fig. 99, a certain number of times until the pointer of the dial is over the required signal. For instance, if the signal

to be given is number "6" on the dial the lever is moved forward six times. This has the effect of placing the pointers of all the instruments (with the exception of the receiving instrument in the winding engine house) over signal number "6." Simultaneously at each point the acoustic signal is sounded a corresponding number of times. When ready for the order to be carried out by the engineman, the banksman at the surface passes it on to him by merely pressing once a "carry-out" push (not shown in illustration). This causes the signal number "6" to be recorded on the dial of the receiver in the engine house and the electric hooter or bell, as the case may be, to sound six times, whilst the pointers on all the other instruments automatically return to the zero point unaccompanied by any audible signal. The signal thus given remains on the engineman's instrument until a fresh signal is transmitted. In case of pressing danger, another signal (differing in tone from the other alarms) can be given by pressing the emergency push. This signal is sounded at the surface and in the engine house. The principle on which the instruments and system are constructed and arranged is illustrated by the diagrams (Figs. 101 and 102).

The Combined Transmitter and Receiver.—In each of the instruments at the various points there is a recorder, the construction of which is illustrated by the diagram (Fig. 101). On referring to the diagram it will be observed that this recorder is furnished with three electro-magnets M^1, M^2, M^3, the iron cores of which slide in and out when the current is sent through the respective windings. The electro-magnets are arranged in a circle round a centre crank, to which latter the

movable cores are coupled. The angular displacement of each electro-magnet with respect to the others is 120 degrees. To turn the centre crank round once in the direction of the hands of a clock a current impulse would have to be sent through electro-magnet M^3, another through M^1, and a third through M^2. The crank is geared by a small pinion to a large cogwheel, R, on whose shaft there is a pointer. It is obvious that by choosing the proper proportion between the two gear wheels the pointer can be moved to any desired number on the dial in front of which it is placed. By reversing the direction of the motion of the brush, L, the battery, B, can be made to send the successive impulses through the electro-magnets in the reverse order, so that the pointer moves in the opposite direction.



RECORDING SIGNALLING APPARATUS

FIG. 101.

The Automatic Switch. — The function of the automatic switch is to store up the signal given at any point and to pass the signal on to the engineman when the banksman depresses the "carry-out" push. When the principle on which the storing up of the signal is based has been grasped the rest of the system is easy to understand. The principle can be readily

explained by means of a simplified diagram (Fig. 102). On this diagram the recorders on the bank and down the mine shaft only, and the corresponding bells or hooters are shown. At the bank the "carry-out" push only, and in the mine the signalling lever only, are in evidence. The rest of the apparatus has been left

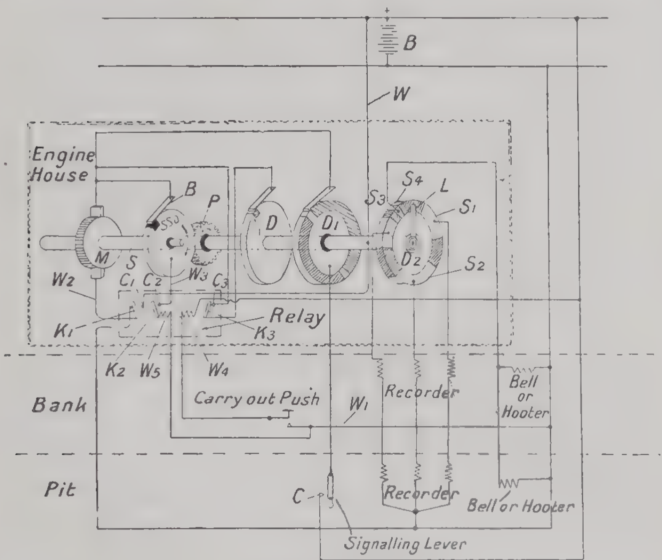


FIG. 102.

out as it is unnecessary for the purposes of this description. The apparatus inside the double dotted lines represents the automatic switch. M is a motor coupled to a shaft, S, on which are fixed a pinion, P, and two discs, D and D¹. The pinion, P, drives the signal storing disc, SSD. A brush, B, bears on a piece of insulating material fixed on the edge of the disc,

SSD. Disc D has also a small segment of insulating material on which a brush bears until the disc is moved and its metallic part brought in contact with the brush. Disc D^1 has a rim of insulating material, except at one point where the brush bears on a segment forming a part of the solid metal. Disc D^2 is stationary, so that when the motor turns the shaft the brush, L, is brought into contact with the segments, S^1, S^2, S^3, and S^4, in succession. The order in which contact is made with these segments is reversed when the motor runs in the reverse direction. The slightest turn of the pinion, P, will cause the metallic part of the disc, SSD, to be brought into contact with the brush, B. Assuming that an onsetter in the mine wishes to give a signal corresponding to point "3" on the recorders. To do this, he brings his signalling lever into contact with C three times. *Each time the lever is brought into contact with C* the following circuit is closed, and the following functions are performed by the automatic switch :—

The circuit closed may be traced from the + pole of the battery, B, through the signalling lever, disc D^1, motor, armature, K^1 of the relay and back to — pole of the battery. The motor instantly turns the shaft and breaks the contact at disc, D^1, but at the same time causes contact to be made at D, so that the current is kept flowing from + of the battery through wire W, shaft, disc D, K^3 of relay and through the motor to — pole of the battery. The shaft, therefore, has to make a complete revolution before the contact with the brush on disc D is broken again by the segment 1. This one revolution of the shaft will have caused two distinct functions to have been performed :—

(1) A current impulse will have been sent through

the medium of brush, L, through each of the three coils of each recorder, and through the bells or hooters. The pointers of the recorders will, therefore, have moved on to the next point on the dial, and the bells or hooters will have sounded once.

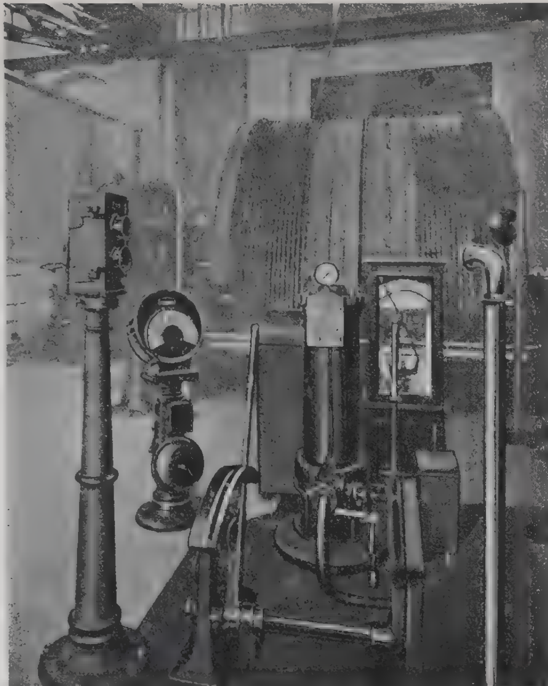
(2) The pinion, P, will have turned the disc, SSD, round a certain distance. (The signal storing disc, SSD, is so geared as to make only one complete revolution when the shaft, S, has turned round the maximum number of times.) The slightest turn of the shaft will suffice to bring brush, B, into contact with the metallic part of the disc, SSD. The pinion, P, having been turned round three steps through the signalling lever being brought into contact with C three times, the "carry-out" push is now depressed by the banksman. A current will thus flow which may be traced from the — pole of the battery, through W^1, "carry-out" push, winding W^1 of relay to + pole of battery B. The armature springs, K^1, K^2, and K^3, then come into contact with C^1, C^2, and C^3, and current commences flowing through winding, W^3, to the motor. As the current is now sent through the motor in the opposite direction to that which flowed when the signalling lever was operated, the motor will turn back the shaft, S, until the insulating segment on SSD comes under brush B again. That is to say, the shaft, S, is now turned backward exactly the same number of times as it was previously turned forward, and the pointers on the recorders are also moved back to the starting point. When the current ceases flowing through the motor by virtue of disc SSD, the relay releases and the springs, K^1, K^2, and K^3, go back into their normal positions.

It is obvious that another pointer could be fitted in

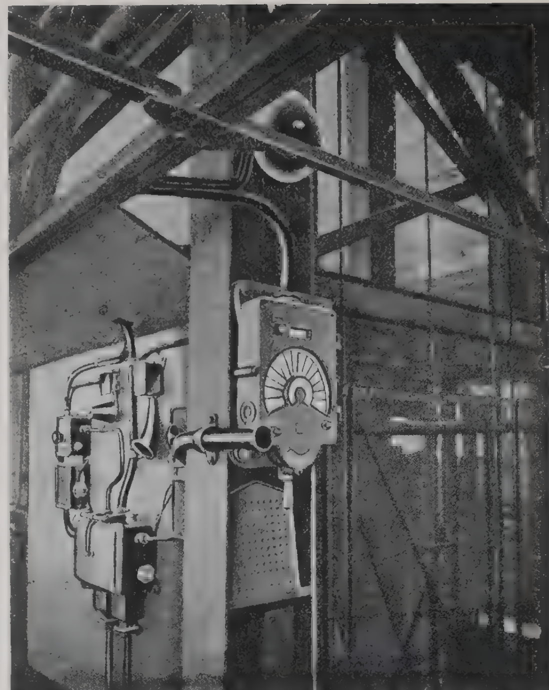
the engine house, which could be made to move forward exactly the same number of steps as the bank and level recorders are moved backward.

As it was assumed at the outset that signal No. 3 was to be given, the shaft, S, was caused to make three complete turns before the "carry-out" push was depressed. When the "carry-out" was depressed the shaft, S, was turned back three complete turns by virtue of the signal storing disc, SSD.

ADNIL MINE SHAFT SIGNAL APPARATUS.



RECEIVER IN ENGINE HOUSE.



COMBINED TRANSMITTER AND RECEIVER AT BANK OF MINE.

CHAPTER VIII

ELECTRIC SHAFT SIGNAL WIRING

In cases where the wiring diagram entails only a small number of conductors, single wires may be used for shaft wiring. When four or more wires are comprised in the system it is preferable to form them into a multicore cable, which may be armoured or not, as circumstances dictate. Signal wires should in all cases be run on the opposite side to electric light or power cables, if these pass down the same shaft. If the signal cables are armoured, the armouring should be effectively earthed, so that any induced electro-motive force may be discharged at once.

Insulation of Shaft Wires.—Bare wires are sometimes run in the shaft, but are seldom satisfactory, and one of the wires at least should be insulated. A suitable class of insulated wire adapted for the purpose is that used for electric lighting service. This may be composed of a single copper conductor of not less than No. 14 gauge wire (or the equivalent stranded conductor) tinned and insulated with pure and vulcanised india-rubber, taped and braided and coated with preservative compound.

Fixing Insulated Wires in Shafts.—The simplest method of fixing single insulated wires in shafts is to support each wire from a porcelain bobbin or reel

insulator fixed to the brickwork, or timbering, at the top of the shaft and attached to another insulator at the bottom. If the wires are liable to be damaged, they should be enclosed in continuous wood casing, which may be fixed to the side of the shaft. The casing should be made of well-tarred timber of substantial thickness, and should be supported on distant pieces so that there is a space left between the casing and the brickwork for the free passage of water. The wood casing should have a rather deep groove into which the wires fit tightly, and are thus supported as well as enclosed. A wooden mallet should be used when placing the conductors in the grooves to prevent any risk of damage to the insulation of the wires. After being gently forced into place the wires may be covered with a thin wood board or capping, care being taken to keep all nails, used for the purpose of securing the covering to the casing, well away from the wires. Iron pipes or conduits are not to be recommended as a protection for covered wires in shafts. They are more expensive than wood casing, cost more to fix and often corrode through the action of the water present in the shaft, which is frequently charged with mineral salts and other corrosive materials. The wires are furthermore liable to be damaged while being drawn into the conduits, and when once fixed, examination for faults and repairs becomes exceedingly difficult.

Jointing Shaft Wires.—Unless specially manufactured, the insulated line wires used for shaft signalling are usually delivered in coils or cut lengths, varying from 100 to 110 yards (one sixteenth of a mile). If the shaft is deeper than this it will be necessary to joint on extra lengths of insulated wire until the required

continuous length is made up. Wherever possible, the joints in the insulated wires should never be made in the shaft itself, but if jointing cannot be avoided, they should be made on the surface and under cover. A joint is made in an insulated wire in the following manner: The two ends to be jointed together are taken and all braiding carefully removed for a distance

FIG. 103.

of about 2 inches from each of the ends. The india-rubber insulation is then cut back for a somewhat shorter distance, so that a space of about $\frac{1}{2}$ inch separates the copper conductor from the braiding, the india-rubber installation being preferably tapered away from the copper conductor, as shown in Fig. 103. The copper conductor is then scraped perfectly clean,

FIG. 104.

and the two ends twisted together in the manner shown in Fig. 104. The joint thus made in the copper conductor is preferably soldered. A strip of pure india-rubber tape is then put on under tension, making three or four layers, each layer breaking joint with the one below, and all commencing well back on each side of the joint. Some jointers at this stage rub a small quantity of india-rubber solution over the last layer of rubber, and this, if not used in excess, has the effect of making

all solid. If, however, too much is used, it eventually rots the insulation of the joint. In any case, if used, a short time should be allowed to elapse, to enable the

FIG. 105.

rubber solvent to evaporate before finally finishing the joint. This is effected by wrapping the joint with a layer of waterproof adherent tape. A finished joint is illustrated in Fig. 105.

Multicore Cables.—When the conditions favour the use of a multicore cable a suitable specification is as follows :—

" Each conductor of No. 18 S. W. gauge or No. 16 B. and S. gauge tinned copper wire.

" Insulated with pure and vulcanised india-rubber ; taped.

" The insulated conductors twisted together.

" Sheathed with a solid tube of vulcanised bitumen compound, ribbed internally to fit the interstices ; taped.

" Jute served and compounded.

" Armoured with a single layer of galvanised mild steel wires.

" Jute served and thoroughly compounded over all."

These multicore cables usually work well for a very long period, but if a fault eventually develops in any of the cores it is a difficult matter to locate the defective part and make a satisfactory repair. For this reason it is the best practice to include one or two spare

insulated wires in the cable over and above the actual number required in the first instance, so that one or more of these spare cores may be substituted and brought into service in place of any core which may develop a fault in working. The actual prime cost of these extra spare cores is comparatively small, while by their inclusion in the cable, a large future expense may be saved in repairs. They also serve a useful purpose in enabling tests of the wiring to be carried out while the system is actually in use, and without interfering with the working of the same.

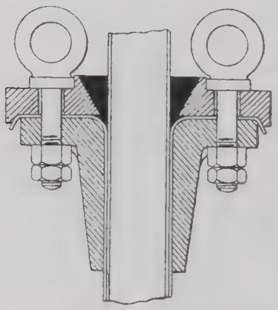


FIG. 106.

Suspension of Armoured Cables.—There are two generally recognised methods of fixing armoured cables in shafts, viz., by *single suspension* and by means of *cleats.*

Single Suspension. — Fig. 106 shows a method of single suspension from the top end of the shaft only, suitable for armoured signal bell cables. An iron cone bored in the centre to take the cable, as measured over the armouring, is passed over the cable, and the armouring wires cut and bent over at right angles and gripped firmly by a top plate held down by four bolts. The centre hole in the top plate, through which the cable passes, is countersunk, and the cap thus formed is filled in with bitumen or other waterproof compound to prevent corrosion of the armouring at this point. The whole is suspended by means of a galvanised steel rope or chain from some convenient point at the top

of the shaft. The objection to this method of suspension is that the armouring wires must be cut, in order to secure a grip on the cable, and this forms a weak point in the cable. In most cases it is preferable

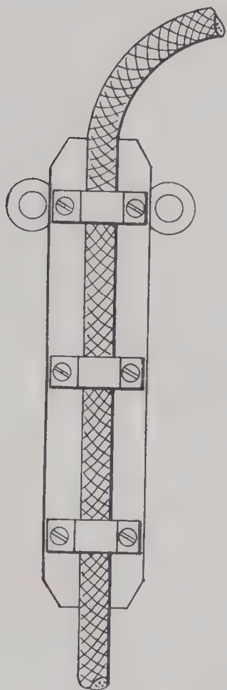


FIG. 107.

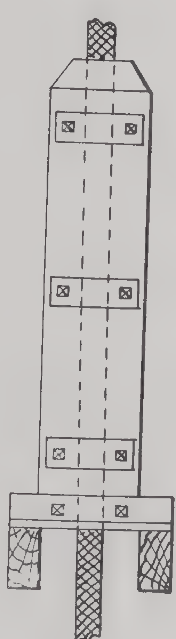


FIG. 108.

to employ some means of suspension whereby the cable, with the armouring intact, is carried direct into a terminal or connecting box fixed in some position at the top of the shaft, as near to the signalling apparatus as possible. Fig. 107 shows an alternative method of

suspension suitable for use under these conditions. A clamping device is employed, consisting of a steel or iron plate provided with a number of steel clamping

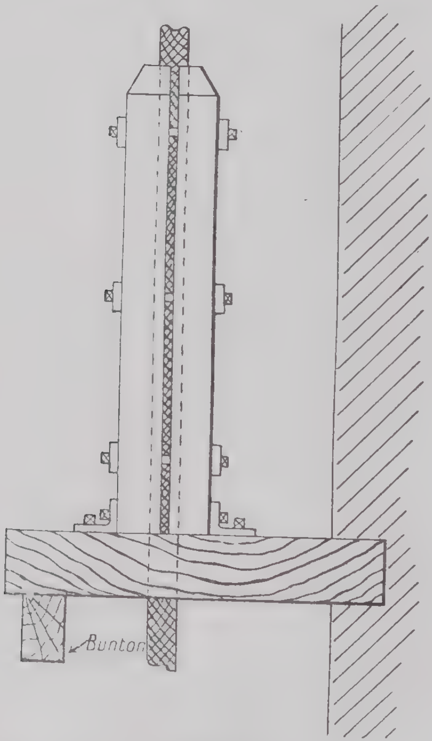


FIG. 109.

pieces. The cable has split steel bushes fitted around it, through which it is gripped by the clamps, so that a succession of grips is obtained without the cable being squeezed out of the circular shape. The clamp, with the cable attached, is suspended by means of wire

ropes threaded through eyelets formed in the clamp, as shown in Fig. 107.

Wood Cleats.—The method of fixing armoured cables by means of cleats is that generally adopted for shaft wiring. The cable is fixed behind the " buntons " which serve to support the cleat and deflect coals and other falling materials in the shaft. The usual form of cleat employed is that shown in Fig. 108. The cleat is made from a block of some hard wood, such as elm or pitch pine. The latter wood is preferable, as the resin in the pine assists the grip of the cleat on the cable and resists absorption of water. Oak is not

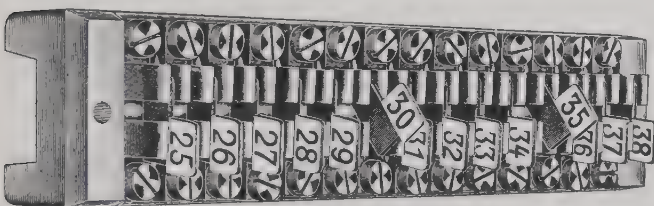


FIG. 110.

suitable because of the tannic acid which it contains. A hole is bored lengthwise through the wood block to the exact size of the cable. The block is then sawn in half, the two halves being clamped together by means of iron straps and bolts. After the cable has been pressed into the grooves, the thickness of the material removed by the saw cut is sufficient to give the necessary grip on the cable. The dimensions of the individual cleats and the number required will depend on the weight of the cable. Various methods of fixing the cleats in the shaft are employed, this being

determined by the individual circumstances. A simple method is that shown in Fig. 109. The cleat is bolted to short pieces of angle iron, which are in turn fixed to wood battens which are supported at one end by the bunton, and the other by being let into the brickwork forming the wall of the shaft.

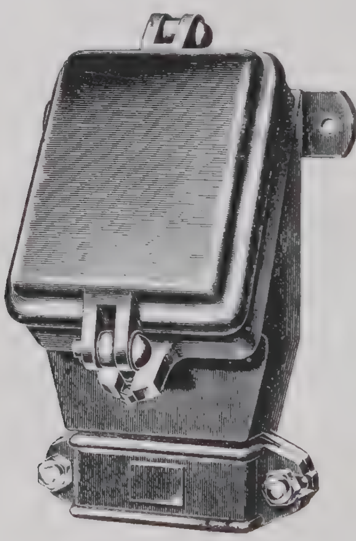


FIG. 111.

Shaft Wiring Terminal Boxes.—It is good practice to have terminal or *link* boxes fixed at each end of the shaft wires or cables. This prevents the frequent necessity of making joints at these points and greatly facilitates the testing of the wiring and localisation of faults. A suitable form of terminal box consists of an insulating slab of ebonite, or porcelain, having mounted upon it the required number of terminals arranged so

that the shaft wires may be entirely disconnected from the remainder of the circuit. A device of this kind is shown in Fig. 110. It will be noted that two sets of terminals are provided, one set being connected to the shaft wires and the other set to the bell and battery circuit, etc. The two sets of terminals are normally connected by a number of metal bars or *links* which, in the terminal board shown in Fig. 110, are held in place by spring clips and numbered so as to make identification of the various wires and circuits an easy matter. The terminal boards may be enclosed in teak, oak or other hardwood cases, when placed in a dry position, but when armoured cables are used an iron box fitted with watertight glands and cover, as shown in Fig. 111, should be provided.

CHAPTER IX

ELECTRIC ENGINE PLANE SIGNALS

THE engine plane signalling system, which controls the traffic on the underground haulage roads and engine planes is now almost invariably operated electrically. In this system of signalling the usual arrangement is to place a bell and battery in the engine house, which may be situated either at the level or bottom of the shaft or on the surface. The bell, which may be either single-stroke or trembling, is fixed as near to the engineman as possible, while the battery is placed in any convenient position where it may have the advantage of a moderate temperature at all times and which is also dry. The bell and battery are connected to two bare wires, which run the full length of the engine plane. These bare wires are fixed on porcelain, stoneware, or glass insulators, and are stretched at such a distance apart that they can either be pinched together with the hand or bridged across with a spanner, or any other convenient method. By means of this simple arrangement the bell can be rung and a signal transmitted from any point on the haulage road by simply bringing the two wires together or otherwise short-circuiting them. This constitutes the simplest possible arrangement of engine plane signalling which, however, may be elaborated to almost any extent. Where the hauling

engine is on the surface a second bell may be inserted in the circuit at the bottom of the shaft to ring with the engine house bell, so that the onsetter will be informed of all that is taking place on the engine plane. If it is necessary for the roadman to be informed when the haulage is stopped, bells may also be inserted at the various stopping places on the road where desired. At these stations suitable ringing keys or tappers are fixed for working the signals, but at all other places along the road the signals are given by merely pressing the two wires together.

Sectional Signalling System.—Where a number of districts are being worked underground, or the haulage road is of any considerable length, it is essential for the engineman to be informed from what point on the road the signals for stopping or restarting the hauling engine are being sent. A method of performing this duty is to assign a definite number of raps or rings of the signal bell to distinguish each of the different roadmen, but this is not an infallible system as it is quite possible for two or more men to signal simultaneously, thus leading to a confusion of signals taking place. The only reliable system to instal under these circumstances is the *sectional* system. This system necessitates the dividing up of the engine plane, or haulage road, wiring into sections corresponding to the various districts, or to convenient lengths of roadway, and the provision of a suitable indicator in the hauling engine house for the guidance of the engineman. He is thus enabled to distinguish the origin of the signals and ascertain definitely, before restarting the hauling engine, after receiving the signal to stop, that the signal to restart has been given from the same section as transmitted

the stopping signal. It is most important that undeniable evidence of this be transmitted to the hauling engine house, as otherwise the train of tubs may be started inadvertently by an attendant when another attendant wishes it to remain stationary, leading possibly to loss of life or serious damage to the mining equipment.

Bell Signal Relay Installations.—When the underground signalling circuits are of some considerable length it may be found that an excessive voltage is necessary to ring the different signal bells efficiently. On the other hand, on a wet haulage road there is likely to be considerable leakage between the wires, and in such circumstances the actual voltage on the lines should be kept as low as possible. Either of these conditions favours the introduction of a system of relay working. One or more relays of the type shown in Fig. 26 are inserted in the main circuit of the line wires in place of the signal bells which are rung by a local battery actuated by the relays. In following out this system the actual voltage required on the main lines may be kept at an extremely low value resulting in a minimum of leakage without any reduction in the efficiency of the system taking place.

Engine Plane Signalling in Gaseous Mines.—The system of bare wire signalling on engine planes is not suitable for use in gassy mines, as owing to the sparking which occurs when transmitting a signal, through contact with the bare wires, any inflammable gas which may be present in sufficient quantity is liable to be ignited. For mines of this description it is necessary to employ conductors insulated throughout with india-rubber or other suitable insulating material, such as are

used for electric lighting service. These insulated line wires may be fastened to porcelain or glass insulators or a multicore cable may be employed which may be insulated and armoured in a similar manner to shaft cables. This system necessitates the use of a number of gas-proof press buttons or ringing keys, one of which is placed in each of the refuge holes along the haulage road.

Mechano-Electric Engine Plane Signalling Apparatus. —Perhaps the most favourable feature of the bare wire signalling system is the facility it affords for immediately transmitting a signal from any and all points on

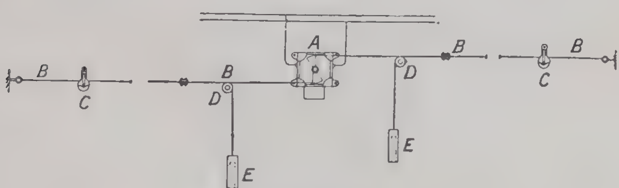


FIG. 112.

the haulage road throughout its length. Any system which takes away this advantage must compare unfavourably with it in efficiency. Unless, therefore, the gas-proof ringing keys are placed at extremely short distances apart along the haulage road a considerable delay must ensue before a signal can be transmitted to the hauling engine house. With a set of tubs off the road, or other like trouble, the delay of a few seconds in transmitting a signal may quite easily have serious consequences. Many systems have been devised with a view to combine the advantages of the bare wire signalling system with the safety required and inherent in a continuously insulated system.

The *Davis-Fryar* mechano-electric signalling system described herein commends itself as practical and reliable and easily maintained in working order. The system is illustrated diagrammatically in Fig. 112.

A contact-maker, A, of special construction is placed in a position where required, and actuated by flexible galvanised iron or steel wires which run along one side of the haulage road. These wires, which are carried by small supporting pulleys, are anchored at the end remote from the contact-maker, and pass over a pulley

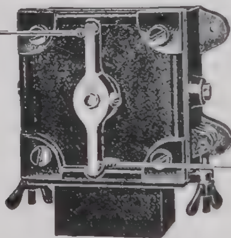


FIG. 113.

near to it, and are kept taut by means of weights. Near to the last-mentioned pulley one end of a short length of flexible wire is secured, and the other end is attached to the contact-maker. The electric contact is contained in a strong cast-iron case, as shown in Fig. 113, which is gas proof, the actual contact is immersed in oil and a removable cover enables it to be readily examined. It will be noted that the contact maker is double acting, so that the flexible wire may be run right and left, and thus double the length of road is served, *i.e.*, 200 yards of road. It will be seen that a signal can be transmitted by pulling the taut

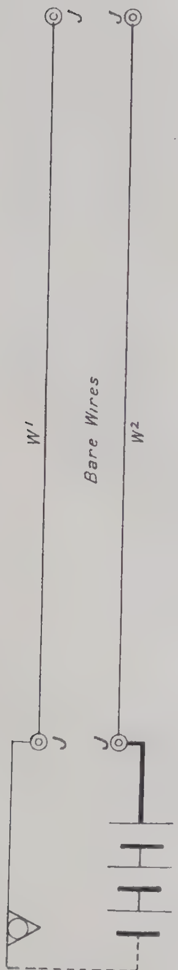


FIG. 114.

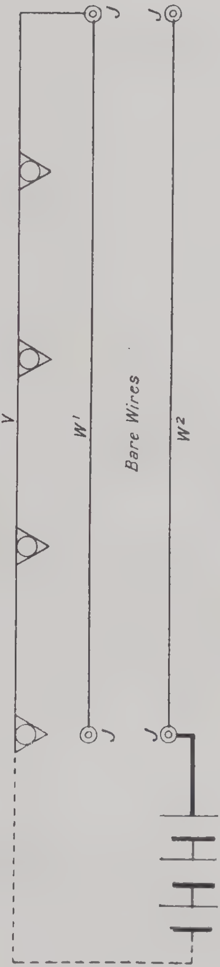


FIG. 115.

flexible wire at any point. The system is considerably less costly than that of installing a sufficient number of gas-proof ringing keys, while it is also more efficient owing to the fact that a signal can be transmitted from any part of the haulage plane, whereas ringing keys can only be fixed at intervals. The line wires required for operating the system are insulated throughout, suitable connections being made to the electric contacts, through water and gastight glands fitted to the cast-iron case of the contact maker.

Engine Plane Wiring Diagrams.—The following diagrams illustrate the various methods of arranging the wiring and accessories used in connection with haulage plane electric signalling. It will be noted that, corresponding to shaft signalling, the various systems may be operated either by a central battery or multiple batteries may be employed.

Bare Two-Wire Signalling Circuit with Central Battery (Fig. 114).—This forms the simplest arrangement of engine plane signal wiring. Two bare wires, W^1, W^2, are stretched on insulators for the full length of the haulage road. The system is operated by a single battery which is placed in the hauling engine house, along with the signal bell. The signals are transmitted from any part of the road by merely short-circuiting the bare wires in any convenient manner.

Three-Wire Signalling Circuit with Bells in Series (Fig. 115).—This diagram shows the arrangement of the wiring when signal bells are required to ring at the various stopping places or *turn-outs* along the haulage road, in addition to the signal bell in the haulage engine house. The two wires, W^1, W^2, are bare wires

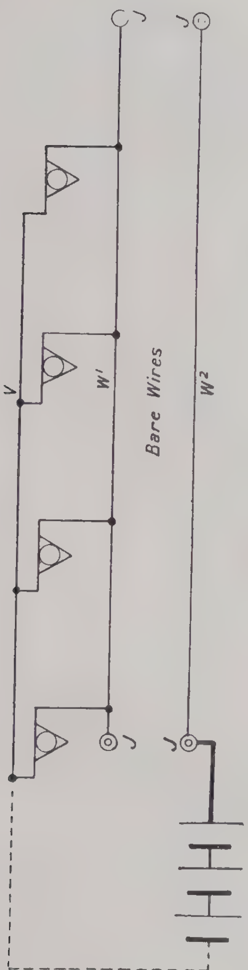


Fig. 116.

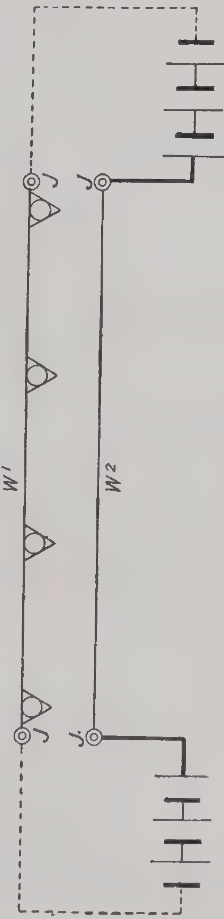


Fig. 117.

which are stretched on insulators, J, along the haulage road. The wire, V, is insulated throughout with a covering of vulcanised india-rubber or similar material, and is used for connecting the signal bells and battery together and to the bare signalling wires. The signal bells are connected in series and may be either single-stroke or shunt or differential trembling bells. All the signal bells are rung simultaneously by bridging across or otherwise short-circuiting the two bare signalling wires, W^1, W^2.

Three-Wire Signalling Circuit with Bells in Parallel (Fig. 116).—This diagram differs only from the preceding in that the signal bells are arranged in parallel. They may be either single-stroke or ordinary trembling bells may be used. W^1, W^2, are the bare signalling wires, V being the insulated connecting wire.

Two-Wire Signalling Circuit with Bells in Series (Fig. 117).—It will be noted that in this system only two wires are required to ring any number of signal bells in series along the haulage road and in the engine house. The two bare wires, W^1, W^2, are stretched on insulators, J, and the signals are transmitted in the usual manner. In this arrangement, unless a third wire is employed, as shown in Fig. 115, it is compulsory to have a battery at each end of the line, otherwise only those bells between the battery and point of signalling will ring.

Two-Wire Signalling Circuit with Bells in Parallel (Fig. 118).—In this arrangement of the wiring, any number of stopping places or turn-outs on the haulage road are each provided with signal bells and battery arranged in parallel on the bare signalling wires, W^1, W^2. The whole of the bells are rung simultaneously

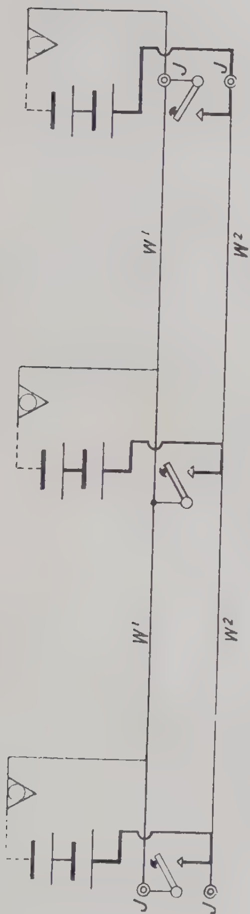


Fig. 118.

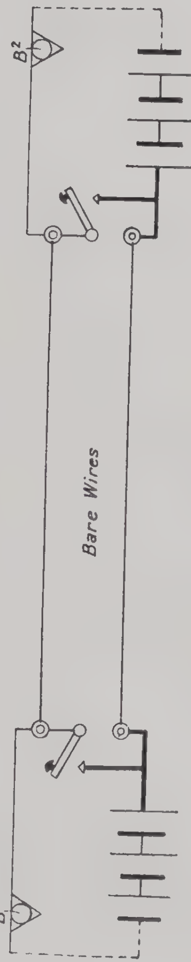


Fig. 119.

by pressing any one of the ringing keys provided at the stopping stations, or by pressing the two bare wires together in the ordinary manner.

Two-Wire Signalling Circuit with Multiple Battery (Fig. 119).—Both signal bells B^1, B^2, can be rung from either end of the haulage road by depressing the ringing keys which make a connection between the two line wires, or by short-circuiting the bare line wires at any point on the engine plane.

Haulage Plane Signalling Circuit. Sectional System with Indicator. (Fig. 120).—A bare positive signalling wire, W^1, is strung on insulators, J, along the full length of the haulage road. The negative wire, also bare, is divided up into any convenient number of sections, S^1, S^2, S^3, each of which is insulated from the other and from the positive wire. A wire, V^1, V^2, V^3, insulated throughout its entire length, is connected to each of the bare section wires and taken back to an indicator fixed in the hauling engine house. The indicator, which is preferably of the luminous signal type, is provided with a signal bell and a central battery operates the entire system. The signals are transmitted to the engine house by pressing the bare wires together, or otherwise short-circuiting them, at any point on the haulage plane, in the usual manner. The section from which the signal originates is recorded on the indicator, while the signal bell indicates by the number of its strokes or rings the nature of the signal.

Engine Plane Signalling Circuit with Relay (Fig. 121). —When the line circuit is of some considerable length or very wet conditions prevail so that either an excessively high or low voltage is necessary to operate the signalling system, one or more relays may

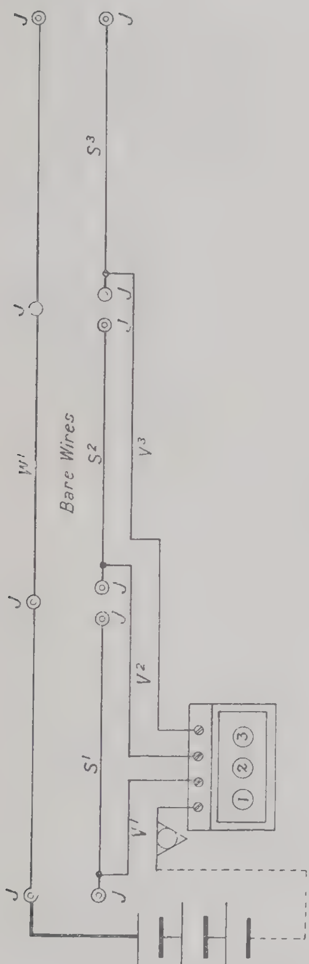


FIG. 120.

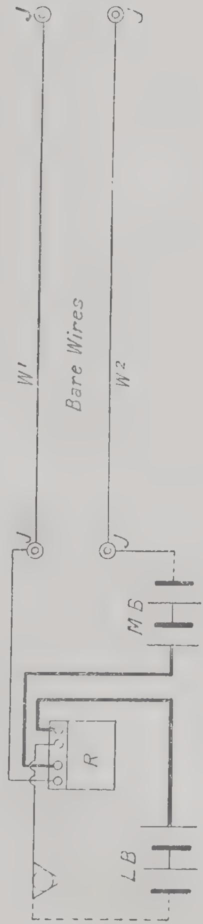


FIG. 121.

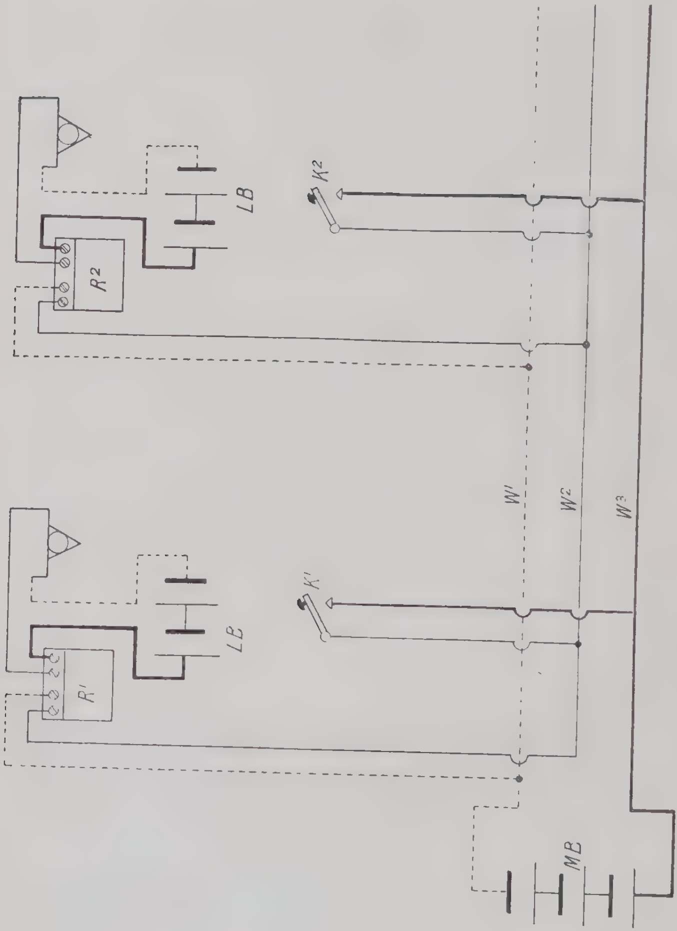


FIG. 122.

be employed with advantage.

Fig. 121 illustrates the principle of relay working as applied to underground signalling circuits. W^1, W^2 are two bare signalling wires stretched on insulators, J, in the usual manner. MB is a main battery composed of any convenient number of cells according to the voltage required to operate the system. This battery may be placed in any convenient position on the haulage road or in the engine house. R is an ordinary relay of the type illustrated in Fig. 26. The relay, together with the signal bell and local battery, LB, are placed together as close as possible in the hauling engine house. When a signal is transmitted from any point on the haulage road the signal bell is rung by the relay contact closing the circuit containing the local battery, LB.

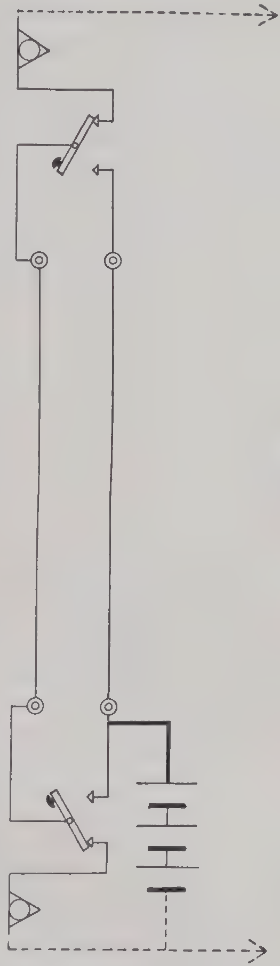


FIG. 123.

Three-Wire Haulage Plane Signalling Circuit Multiple Relay System (Fig. 122).—The whole of the signal bells, situated in the hauling

engine house and at the various turn-outs on the haulage road are rung by means of the local batteries, LB, which are actuated by relays, R^1, R^2. Three insulated line wires, W^1, W^2, W^3, are employed, W^1 being the negative or return wire. The relays are connected in parallel between the line wires, W^1 and W^2, and the ringing keys, K^1, K^2, connect the line wires, W^2 and W^3. The main circuit is operated by the main battery, MB. All the bells are rung simultaneously by depressing any of the ringing keys, K^1, K^2.

Morse Key Signalling Circuit (Fig. 123).—Either bell is rung by depressing the Morse keys situated at the opposite end of the haulage road. In this instance, the line wires are insulated throughout their entire length.

CHAPTER X

ELECTRIC ENGINE PLANE SIGNAL WIRING

Bare Wire Signal Wiring.—The conductors used for wiring engine planes and haulage roads in connection with the bare wire signalling system are ordinary galvanised iron wires in sizes varying from 150 lbs. to 300 lbs. per mile. The latter makes the neatest job and is also stronger and more durable than the smaller sizes, while by reason of its lower electrical resistance it is also more economical in battery power.

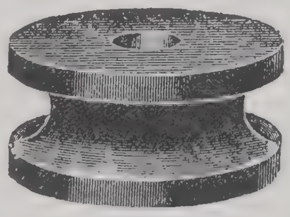


FIG. 124.

Engine Plane Signal Insulators.—The conductors are fixed to porcelain, stoneware or glass insulators, usually of the reel or bobbin pattern, as shown in Fig. 124. These insulators are made in a large number of different sizes, a convenient size adapted for this purpose being 2 inch diameter $\times$ $1\frac{1}{2}$ inch height and with $\frac{1}{2}$ inch hole in centre and groove on periphery $\frac{1}{2}$ inch width and depth.

Fixing Insulators.—The insulators are fixed by means of a coach bolt or screw passed through the centre hole and either screwed into the props on the

side of the road, as shown in Fig. 125, or into the roof timbers. Where roof timbers are absent and it is not convenient to utilise the props on the sides of the roads, the "post stone" forming the roof is plugged with hard-wood plugs and the insulators fastened to these. The two bare line wires are kept about 8 inches apart, which is a convenient distance for making contact between them with a lamp or metal tool of any kind when it is necessary to signal from any point on the road. Going round curves the insulators may be required every few feet, but on a straight road they will only need to be fixed at distances varying from 10 to 15 yards apart.

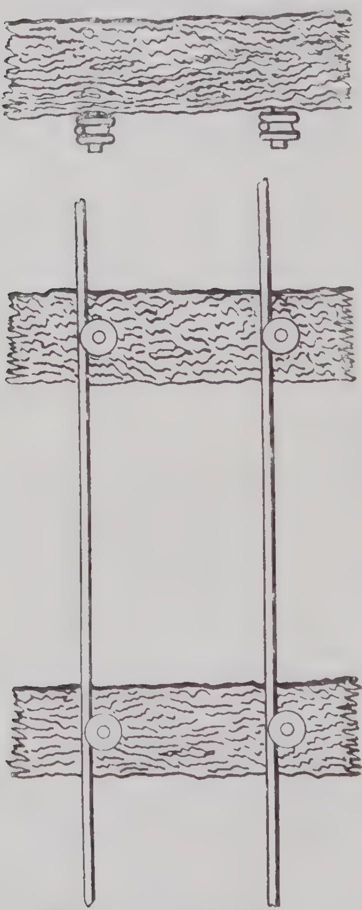


FIG. 125.

Shackle Insulators.—On very wet and steamy roads, which are often met with, a serious amount of

leakage is liable to occur if suitable precautions are not taken to prevent it, so much so that the signalling system is frequently rendered inoperative by reason of the moisture condensing in drops and running down the insulators. Under these conditions the reel type of insulator is not applicable and the shackle insulator, as illustrated in Fig. 126, is adopted. The shackle insulator is designed to be fixed in a horizontal position only, and it will be noted that it is provided with two lips to shed off the water so that the effects of leakage are minimised to the greatest extent. The shackle insulator is fixed in position by means of a screw bolt passed through a hole in its centre in a similar manner to the reel or bobbin insulator.

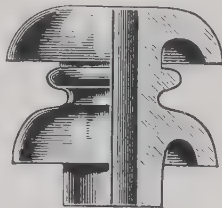


FIG. 126.

Sectional Wiring.—In arranging a scheme of engine plane wiring it is good practice to divide up the wiring

FIG. 127.

into a series of independent sections, each of convenient length for running the line wires in the first instance, and subsequently for use in testing the lines. The ends of the line wires constituting each of the sections are

joined or connected together by means of short lengths of insulated wire, as shown in Fig. 127, the connections being made by means of screw clamps or terminal connectors of the pattern as shown in Fig. 128.

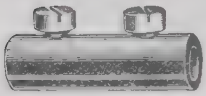


Fig. 128.

Running Line Wires. — In running the line wires, one wire at a time is paid off the bundle or coil, or if possible from a drum, if this can be obtained, which is drawn along the haulage road for a convenient distance. The wire is lifted into the grooves of the insulators and stretched moderately taut by means of a draw vice and key of the

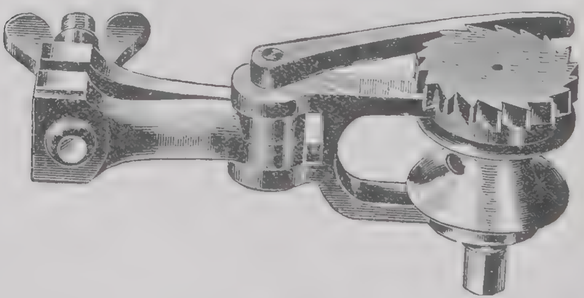


Fig. 129.

pattern as shown in Fig. 129. The line wires are then shackled off and bound to the insulators.

Binding Line Wires to Insulators.—The method of binding iron wires to the insulators is shown in Fig. 130. For the sake of clearness and the better to understand the description, the insulator itself is omitted from the illustration. Annealed galvanised iron wire weighing about 60 lbs. to the mile, is used for the binding wire.

Two laps of binding wire are taken round the line wire at A. The inner end is then taken round the neck of the insulator to the under side of the line wire at B, and, after one complete lap, is then taken back round the insulator to A and lapped on the line wire for about a dozen turns to C. The other end of the binding wire is then taken from the underside of the line wire at A round the neck of the insulator to the upper side of the line wire at B, and then similarly lapped over the line wire to D.

Jointing Line Wires.—If the engine plane signal

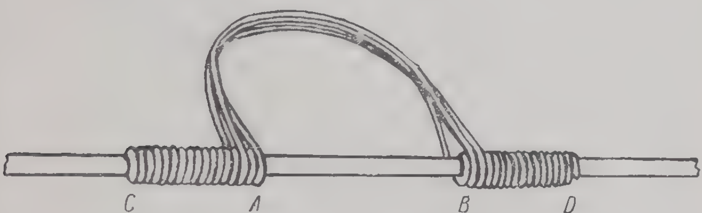


FIG. 130.

wiring is divided up into sections, as referred to, a considerable amount of piecing together and jointing of the line wires will be obviated; in most cases, however, some jointing of the line wires is unavoidable. A number of different methods of jointing line wires are available, but the best kind of joint to employ for large size wires is undoubtedly the Britannia electric mine-signal joint shown in Fig. 131. The binding wire consists of annealed galvanised iron wire weighing 60 lbs. per mile. The length of binding wire required for each joint depends upon the diameter of the line wire to be jointed, varying from a length of 36 inches

for line wire weighing 150 lbs. per mile to 48 inches for line wire weighing 300 lbs. per mile. The overlap required to make a good joint also varies in accordance with the diameter of the line wires, the smaller the diameter the shorter is the overlap necessary, varying from 2 inches in the smaller to $2\frac{1}{2}$ inches in the larger. In making a joint the surfaces of the line wires and the binding wire must be perfectly clean and bright, and the conductors straight and parallel to each other. The free ends of the line wires are turned up at right angles for a space of about $\frac{1}{2}$ inch, as shown in the illustration (Fig. 131). The making of a joint is much

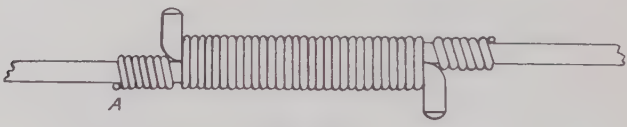


FIG. 131.

facilitated if the ends of the line wires can be held firmly in position, and for this purpose it is convenient to fix them into a hand vice leaving sufficient length of wire projecting to enable one half of the joint to be bound. The binding is started by taking about half a dozen laps of the binding wire around the line wire commencing at A. The left hand portion of the binding should then be completed holding the first few turns securely in position by pinching with the finger and thumb of the left hand and pulling tightly with the right hand at that end of the wire which is being laid on. The joint should then be removed from the hand vice and the right-hand side finished in a similar manner, taking about six or seven turns around the

single wire and neatly finishing off the binding wire, as shown in the illustration. These joints are sometimes soldered, but, if carefully made, this is not absolutely necessary. If soldered, Baker's soldering fluid, Fluxite, or other soldering paste only should be used, and when this has been applied the joint should be quickly soldered, the superfluous metal wiped off with a rag at right angles to the binding wire and the joint allowed to cool in the air. It is important that no ordinary acid flux be used on these joints otherwise the wire will quickly corrode and for the same reason as little as possible of the less harmful fluxes referred to should be left on the joints.

Twist Joints for Line Wires.—A method of making a joint in the smaller sizes of line wires is that shown in Fig. 104. The ends of the wires having been thoroughly cleaned are laid side by side, overlapping for a length of about 8 inches and twisted together for a distance of about $1\frac{3}{4}$ inches, the twist here having a lay of about $\frac{1}{2}$ inch. Each end should then be tightly wrapped around the other wire for a length of about $\frac{3}{8}$ inch, thus making the completed joint about $2\frac{1}{2}$ inches long, the ends being cut off with the pliers. The joint may then be soldered or not as may be decided upon. The two wires should be twisted equally in the middle portion as otherwise it has been found that breakage always takes place of the wire which has the greater amount of twist.

Shackling off Line Wires.—At all terminal points where the line wires begin or end, such as at the various sections and turn-outs on the haulage road, the line wires are "shackled off" or terminated on the insulators. The terminal insulators being in a position

to take up the whole of the stress due to the weight and tension of the particular length of line wire stretched between them should preferably be of a larger and stronger type than the ordinary line insulators whose duty is merely to retain the line wires in position on the insulators and are in consequence subjected to little or no stress. For this reason the terminal insulators should also be more strongly fixed and with a larger screw bolt. Fig. 127 shows the arrangement

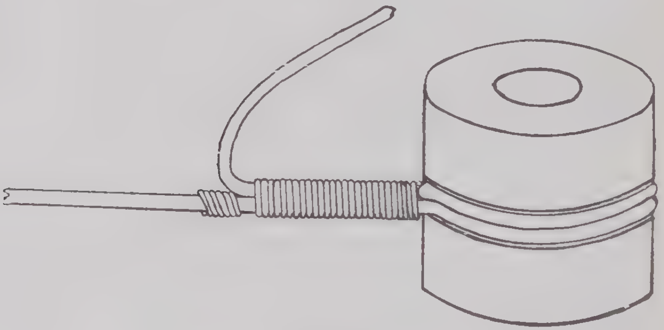


FIG. 132.

of the terminal insulators for shackling off the line wires at a section or junction. The terminal insulators are fixed at a distance apart of about 18 inches, and the line wires are terminated by bending the conductor twice around the insulator and then lapping the double conductor with binding wire after the manner of making a Britannia joint except that a "tail" is left for the connection to the leading-in or connecting wires. Fig. 132 illustrates the manner in which the line wires are shackled off or terminated on the insulators. The

leading-in wires employed for connecting the various sections together or for making connection to the signalling instruments are composed of insulated wires similar to those used for electric lighting service, the conductors being of tinned copper and of No. 16 gauge. The insulated leading-in wires are preferably connected to the bare line wires by means of brass terminal connectors of the pattern as shown in Fig. 128. These connectors serve a useful purpose in that they enable the line wires to be entirely disconnected either in sections or from the instruments without being under the necessity of breaking joints, thus facilitating testing operations if these are necessary at any time.

Table XI.—Double Galvanised Telegraph and Telephone Wire of the Highest Electrical Qualities.

Number Roebling's Gauge.	Diameter in inches.	Weight in lbs. per mile.	Approximate Breaking Strain in lbs.			Average Resistance in ohms at 68° F. per mile.		
			E.B.B.*	B.B.†	Steel.	E.B.B.*	B.B.†	Steel.
4	·225	730	2,190	2,409	2,701	6·44	7·53	8·90
6	·192	540	1,620	1,782	1,998	8·70	10·19	12·04
8	·162	380	1,140	1,254	1,406	12·37	14·47	17·10
9	·148	320	960	1,056	1,184	14·69	17·19	20·31
10	·135	260	780	858	962	18·08	21·15	25·00
11	·120	214	642	706	792	21·96	25·70	30·37
12	·105	165	495	545	611	28·48	33·33	39·39
14	·080	96	288	317	355	48·96	57·29	67·71

* E.B.B. = Extra Best Best. † B.B. = Best Best Iron Wires.

TABLE XII.—GALVANISED IRON SIGNAL WIRES. ORDINARY QUALITY.

Number British Standard Wire Gauge.	Diameter in inches.	Weight in lbs. per mile.	Yards per cwt.	Approximate Breaking Strain in lbs.	Average Resistance in ohms (Iron Wires).	
					Per mile.	Per 100 yards.
4	·234	732	269	2,196	11·25	0·64
8	·192	348	566	1,044	24·00	1.36
11	·160	183	1,077	549	46·50	2·64
12	·104	148	1,333	444	57·00	3·19
14	·080	88	2,240	264	96·00	5·48

TABLE XIII.—SHOWING THE DIFFERENCE BETWEEN WIRE GAUGES.

No.	American or Brown and Sharpe's.	Old English or London.	Birmingham or Stubs.	W. & M. and Roebling.	New British Standard.	U.S. Standard.
0000	·460	·454	·454	·393	·400	·406
000	·40964	·425	·425	·362	·372	·375
00	·36480	·380	·380	·331	·348	·344
0	·32495	·340	·340	·307	·324	·313
1	·28930	·300	·300	·283	·300	·281
2	·25763	·284	·284	·263	·276	·266
3	·22942	·259	·259	·244	·252	·250
4	·20431	·238	·238	·225	·232	·234
5	·18194	·220	·220	·207	·212	·219
6	·16202	·203	·203	·192	·192	·203
7	·14428	·180	·180	·177	·176	·188
8	·12849	·165	·165	·162	·160	·172
9	·11443	·148	·148	·148	·144	·156

TABLE XIII.—SHOWING THE DIFFERENCE BETWEEN WIRE GAUGES—*Continued.*

No.	American or Brown and Sharpe's.	Old English or London.	Birmingham or Stubs.	W. & M. and Roebling.	New British Standard.	U.S. Standard.
10	·10189	·134	·134	·135	·128	·141
11	·09074	·120	·120	·120	·116	·125
12	·08081	·109	·109	·105	·104	·109
13	·07199	·095	·095	·092	·092	·0938
14	·06408	·083	·083	·080	·080	·0781
15	·05706	·072	·072	·072	·072	·0703
16	·05082	·065	·065	·063	·064	·0625
17	·04525	·058	·058	·054	·056	·0563
18	·04030	·049	·049	·047	·048	·0500
19	·03589	·040	·042	·041	·040	·0438
20	·03196	·035	·035	·035	·036	·0375
21	·02846	·0315	·032	·032	·032	·0344
22	·025347	·0295	·028	·028	·028	·0313
23	·022571	·027	·025	·025	·024	·0281
24	·0201	·025	·022	·023	·022	·0250
25	·0179	·023	·020	·020	·020	·0219
26	·01594	·0205	·018	·018	·018	·0188
27	·014195	·01875	·016	·017	·0164	·0172
28	·012641	·0165	·014	·016	·0148	·0156
29	·011257	·0155	·013	·015	·0136	·0141
30	·010025	·01375	·012	·014	·0124	·0125
31	·008928	·01225	·010	·0135	·0116	·0109
32	·00795	·01125	·009	·013	·0108	·0102
33	·00708	·01025	·008	·011	·010	·0094
34	·0063	·0095	·007	·010	·0092	·0086
35	·00561	·009	·005	·0095	·0084	·0078
36	·005	·0075	·004	·009	·0076	·0070
37	·00454	·0065	—	·0085	·0068	·0066
38	·003965	·00575	—	·008	·006	·0063
39	·003531	·005	—	·0075	·0052	—
40	·003144	·0045	—	·007	·0048	—

APPENDIX

BRITISH HOME OFFICE. ABSTRACT OF ELECTRICITY RULES.

Metalliferous Mines Regulation Acts; Coal Mines Regulation Acts.

I. Special Rules for the Installation and use of Electricity in Coal Mines.

These rules shall not apply in the case of any apparatus used above ground except such as may directly affect the safety of persons below ground.

(15) The use of electricity where inflammable gas is likely to be present.

In any part of a mine in which inflammable gas, although not normally present, is likely to occur in quantity sufficient to be indicative of danger, the following additional requirements shall be observed:—

(i.) All cables, apparatus, signalling wires and signalling instruments, shall be constructed, installed, protected, worked and maintained, so that in the normal working thereof, there shall be no risk of sparking.

Signalling.

(17)—(*a*) Where electricity is used for signalling, the pressure in any one circuit shall not exceed 25 volts.

(*b*) Contact makers shall be so constructed as to prevent the accidental closing of the circuit.

(*c*) Adequate precautions shall be taken to prevent

signal and telephone wires from touching cables and other apparatus.

Memorandum.

(11) *Section* (*a*).—If required by the conditions. lightning arresters should also be provided where underground telephone or signal wires are connected to surface telephone or signal wires. It is important that the earthing of lightning arresters should be efficient.

British Home Office Regulations under the Coal Mines Act.

Part II.—Signalling (except in Sinking Pits. Section 53).

"*Winding.*"

(92) The following signals shall be used at all times in connection with winding in shaft :—

(*a*) *For winding persons* :—

(1) When a person is about to descend, the banksman shall signal to the onsetter . . . 3

Before the person enters the cage, the onsetter shall signal to the banksman and to the winding engineman 3

When a person is in the cage and ready to descend, the banksman shall signal to the winding engineman 2

(2) When a person is about to ascend, the onsetter shall signal to the banksman and to the winding engineman 3

Before the person enters the cage, the banksman shall signal to the onsetter . . . 3

When the person is in the cage and ready to ascend, the onsetter shall signal to the banksman and to the winding engineman . 1

(*b*) *For winding otherwise than with persons—*

To raise up	1
To stop when in motion	1
To lower down	2
To raise steadily	4
To lower steadily	5

(93) The manager shall, in the case of a mine where there are entrances into the workings from the shafts at different levels, prescribe the signals to be used to indicate the level to which the cage is to be sent, and in respect of movements of the cage between one level and another level, and shall fix any other signals that may be required.

(94) A notice shall be posted in the engine house and at the pithead and at each entrance into the workings from the shaft containing the foregoing signals and the signals fixed by the manager in pursuance of the preceding regulations.

(95) In connection with every winding engine there shall be provided an appliance which shall automatically indicate in a visible manner to the winding engineman (in addition to the ordinary signal), the nature of the signal until the signal is complied with.

(96) No person other than the banksman or onsetter shall give any signal unless he is an official of the mine or is authorised in writing by the manager to give signals.

(97) The foregoing regulations 92 to 95 shall not come into operation until July 1st, 1914.

"*Hauling.*"

(98) The following signals shall be used in all mines in connection with underground haulage worked by gravity or mechanical power :—

(*a*) *Direct or main rope haulage—*

To stop	1
To lower	2
To wind up	3

(*b*) *Haulage* (*other than endless rope or chain haulage*) *on self-acting inclines*—

To stop	1
To lower	2
When persons are about to travel up or down the incline	4
This signal shall be acknowledged by signalling	4

(*c*) *Main and tail-rope haulage*—

To stop	1
To haul inbye	2
To haul outbye	3
To slack out tail-rope	4
To tighten tail-rope	5
To slack out main-rope	6
To tighten main-rope	7

(*d*) *Endless rope* (*or endless chain*) *haulage*—

To commence hauling	2
To stop hauling	1

(99) When persons are about to be conveyed inbye or outbye, each of the signals required by the foregoing regulations to be given when a set or train of tubs is about to be hauled inbye or outbye, as the case may be, shall be preceded by a cautionary signal of 8.

(100) The manager shall, in the case of a mine where there are several districts, prescribe the additional signals to be used to indicate the districts ; and shall fix any other signals that may be required.

(101) A notice shall be posted in the hauling engine house and at each signalling station containing the system of haulage signals in use at such engine house or signalling station.

(102) The foregoing regulations 98 to 101 shall not come into operation until July 1st, 1914.

Part VI.—Additional Regulations for Sinking.

(185) The winding engineman shall not work the winding engine when men are in the shaft except in pursuance of a signal received from the banksman or chargeman.

(186) When lowering the kibble, the winding engineman shall stop it when it has reached a point three fathoms above the bottom of the shaft or above any cradle or platform upon which the kibble is to alight and shall wait for the signal from the chargeman to let it down.

When raising the kibble he shall stop the engine as soon as the kibble has been raised four feet from the bottom, in order that the chargeman may see that the rope is steadied, and shall not again move his engine until he has received the signal from the banksman or chargeman.

(189)	To raise up	1
	To lower down	2
	To stop when in motion	1
	When men are to ride a preliminary signal of	3

The manager shall fix such other signals as may be required. This regulation shall not apply to any shaft in course of being sunk at the date of this regulation coming into force.

(190) No person other than the banksman or chargeman shall give any signal unless he is an official of the mine or is authorised in writing by the manager to give signals.

AMERICAN BUREAU OF MINES.

Abstract of Mining Rules.

Section II.—Transmission Lines and Cables.

Rule 22.—In all roads where it is necessary for men to travel on foot, all wires, except signal wires, must be placed on the same side of the roadway. Signal wires should,

where practicable, be placed on the opposite side of the roadway from the other wires.

Rule 23.—Small wires for lighting or signal circuits shall be conveyed in pipes or casings, or they may be suspended from porcelain or glass insulators or securely tied to them, so that they do not touch any timbering, coal, or metal. On no account shall staples be used. If metallic pipes are used, they must be earthed, and if not electrically continuous, every section must be earthed. If separate uncased wires are used, they shall be kept at least three inches apart except at lamps or fittings.

Electrical Symbols for Mine Maps.

The United States Bureau of Mines.

The State Mining Law, passed by the Pennsylvania Legislature in 1911, requires that the location of all stationary electrical apparatus forming part of the electrical system of bituminous coal mines, including permanent cables, conductors, lights, switches, trolley lines, telephones, signal bells, and other apparatus, shall be shown on a map, and that the map shall also show the capacity of each motor, generator or transformer, and the nature of its duty. The Federal Bureau of Mines for some time previous to the enactment of the statute just mentioned had been considering the same subject, and had prepared a list of symbols for the purpose. Realising the advantages that will attend the adoption of a uniform system of indicating electrical apparatus on mine maps, the Bureau is issuing the following description of its symbols for the consideration of all who may be interested in the matter. All rotating machines are represented by circles. A list of these symbols is given in Figs. 1 and 2. The representation of switches is simple, as is shown by the symbols in Fig. 3. A list of the symbols for miscellaneous apparatus is given in Figs. 4 to 6.

A list of the symbols for conductors is given below :—

Trolley T	T
Medium and low voltage, bare	B
Medium and low voltage, insulated	I
Medium and low voltage, leaded	D
Medium and low voltage, armoured	E
High voltage, leaded	L
High voltage, armoured	A
Ground	G
Telephone	P
Shot Firing	H
High tension lines on surface	═══

In connection with the letter representing conductors, figures can be used to indicate the number of such conductors that pass any designated point. Regardless of the system used, more or less difficulty will be experienced in clearly representing several parallel conductors on small scale maps. The following plan has been adopted by the Bureau of Mines as most satisfactory for general use : A single dotted line is shown on the map wherever there are any electric wires. The presence and extent of such wires are then apparent at a glance. The number and character of the circuits are shown by symbols placed at points where the circuits begin or end. The symbols are understood to refer to what is passing inbye from the points at which the symbols are displayed. Whenever a circuit or a conductor is added or dropped, a new symbol is placed on the map. These symbols consist of groups of letters, each of which represents a conductor, as defined in the list above. A general idea of the application of these conductor symbols may be obtained from Fig. 7. For the sake of simplicity only one entry is shown. For the sake of clearness, explanatory notes are placed on the maps instead of in the text.

EXPLANATORY TEXT OF FIGURES TO APPENDIX.

FIG. 1.*—SYMBOLS FOR MOTORS.

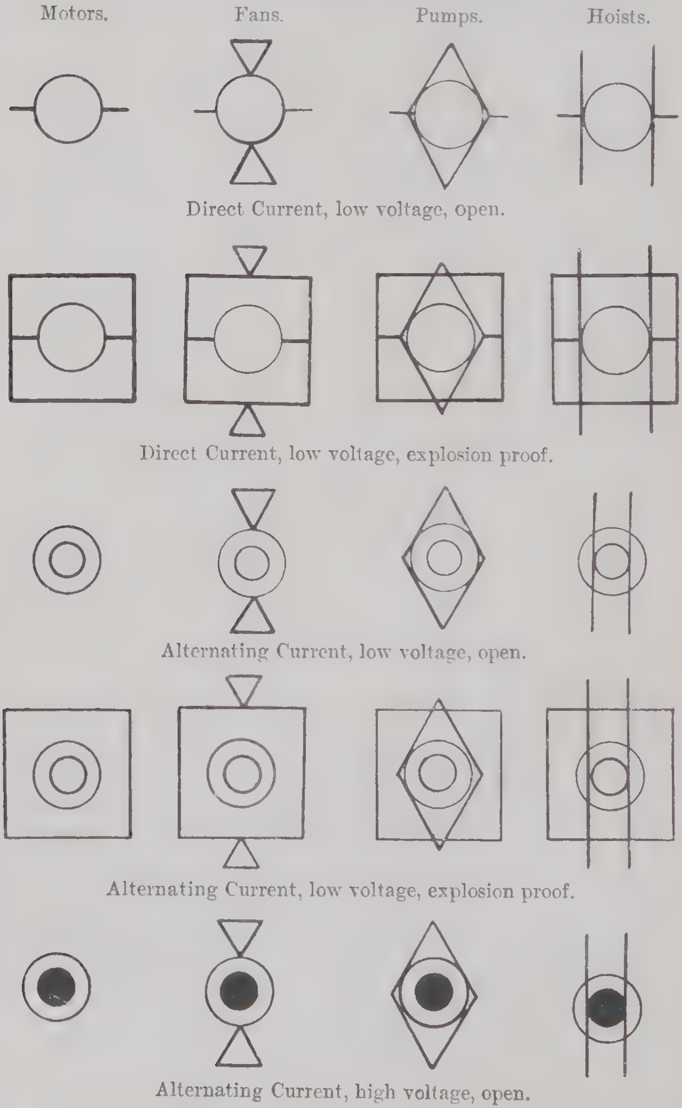
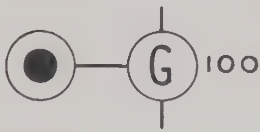


FIG. 2.*—SYMBOLS FOR GENERATORS, CONVERTERS, AND TRANSFORMERS.

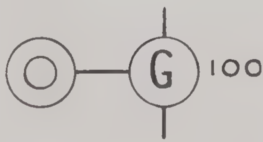
Direct Current . . . . . .

Alternating Current . . . . .

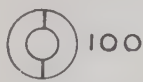
Motor-Generator Set, high voltage motor .



Motor-Generator Set, low voltage motor .



Rotary Converters . . . . .



Transformers . . . . . .

FIG. 3.*—SYMBOLS FOR SWITCHES.

	Switches, Explosion Proof.	Open.
Single Pole, single throw	$\boxed{\$}$	$\$$
Single Pole, double throw	$\boxed{\$^2}$	$\$^2$
Double Pole, single throw	$\boxed{2\$}$	$2\$$
Double Pole, double throw	$\boxed{2\$^2}$	$2\$^2$
Triple Pole, single throw	$\boxed{3\$}$	$3\$$

Fig. 3.*—Symbols for Switches—*Continued.*

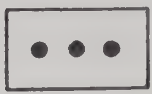
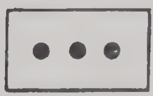
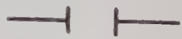
	Switches. Explosion Proof.	Open.
Triple Pole, double throw	$\boxed{3\$^2}$	$3\$^2$
Four Pole, single throw	$\boxed{4\$}$	$4\$$
Four Pole, double throw	$\boxed{4\$^2}$	$4\$^2$
Oil, automatic		
Oil, hand operated		
Automatic trolley		

FIG. 4.*—MISCELLANEOUS SYMBOLS.

Lightning Arresters . . . . 

Switchboards . . . . 

Section Insulators (in trolley) . . . . . 

Bore Holes for Wires . . . . 

Incandescent Lamps . . . . 

FIG. 5.*—SYMBOLS FOR SIGNALS.

Luminous Signal Apparatus . . . . . . 

Signal Bells . . . . 

Telephones . . . . 

Single Cell (Primary or Accumulator) . . . 

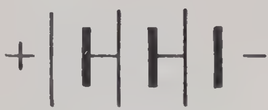
Battery (Primary or Accumulator) . . 

FIG. 6.*—SYMBOLS FOR GROUND CONNECTIONS, ETC.

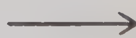
Earth Connections to Earth . . . . . . 

Earth Connections to Pipe . . . . . . 

Earth Connections to Rail . . . . . . 

Cross Bonding of Pipe and Rail . . . . . 

Marginal Note . . . . 

Direction or Source of Power . . . . . . 

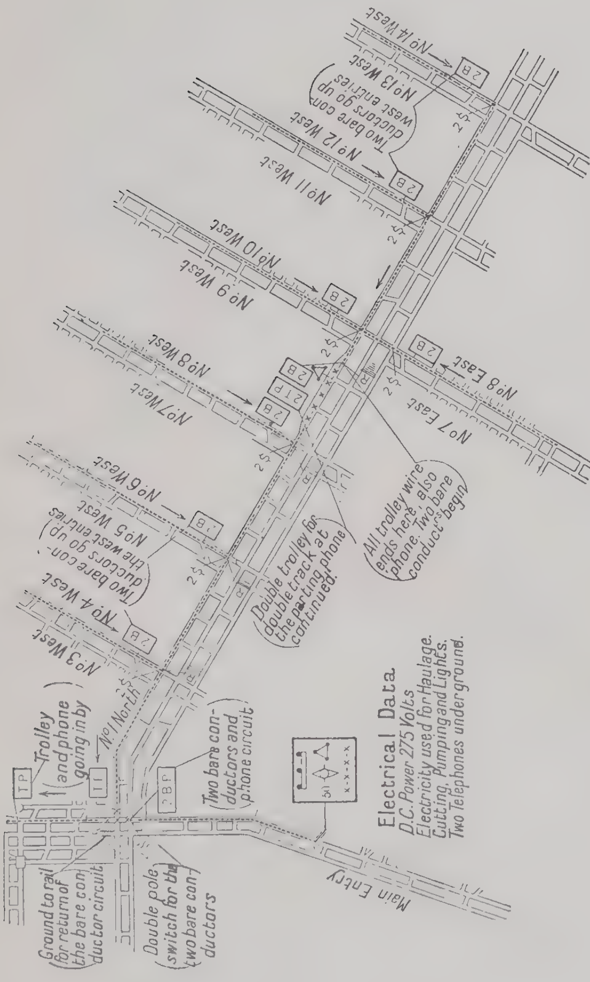

No 14 West
No 13 West
Two bare conductors go up west entries
No 12 West
No 11 West
No 10 West
No 9 West
No 8 West
No 7 West
No 6 West
No 5 West
Two bare conductors go up the west entries
No 4 West
No 3 West
No 8 East
No 7 East
All trolley wire ends here, also phone. Two bare conductors begin
Double trolley for double track at the parting phone continued.
Trolley and phone going in by
No 1 North
Two bare conductors and phone circuit
Ground to rail for return of the bare conductor circuit
Double pole switch for the two bare conductors
Main Entry
Electrical Data
D.C. Power 275 Volts
Electricity used for Haulage, Cutting, Pumping and Lights.
Two Telephones underground.

FIG. 7*.

INDEX

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